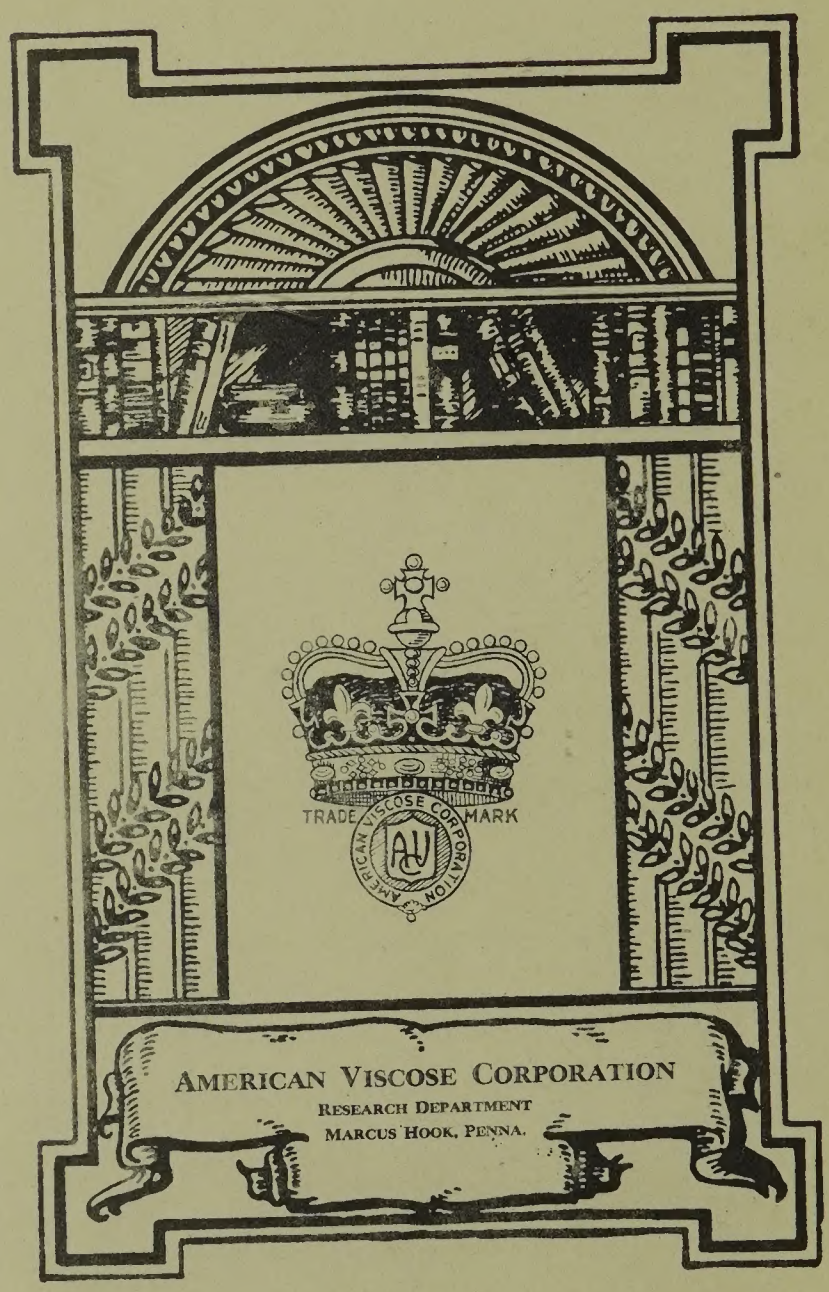
Edward Barlow.

PERIODICAL



J. L. Olsen

TP
1
.C44X

(S) Dm 1-16-81
Edward Barlow

TRANSACTIONS

OF THE

AMERICAN INSTITUTE

OF

CHEMICAL ENGINEERS

VOLUME VIII

1915

OFFICE OF THE SECRETARY
COOPER UNION, NEW YORK, N. Y.

PUBLISHED BY THE INSTITUTE
AND FOR SALE BY
D. VAN NOSTRAND COMPANY
NEW YORK
1916

The Institute as a body does not hold itself responsible for the statement of facts or opinions advanced in papers or discussions.

Copyright, 1916, by
AMERICAN INSTITUTE OF
CHEMICAL ENGINEERS

TABLE OF CONTENTS

		PAGE
Resources and Possibilities of Chemical Industry in the Southwest	EDGAR BARUCH,	1
The Chemical Evidence of Smelter Smoke Injury to Vegetation	J. P. MITCHELL,	25
Cottrell Processes of Electrical Precipitation	WALTER A. SCHMIDT,	35
The Fleming Patent Dust-Collecting System	W. C. HANNA,	65
The Thiogen Process for Removing Sulphur Fumes	S. W. YOUNG,	81
The Manufacture of Cream of Tartar	OTTO BEST,	91
Engineering Features of Wine Making	ARTHUR LACHMAN,	107
The Treatment of Sewage by Aeration in the Presence of Activated Sludge	EDWARD BARTOW,	119
A New Electrolytic Method of Sewage Disposal	J. C. OLSEN,	133
Costs as Applied to Professional Business	RALPH A. GOULD,	162
The Improvement of High Boiling Petroleum Oils, and the Manufacture of Gasoline as a By-Product therefrom, by the Action of Aluminum Chloride	A. M. MCAFEE,	177
Some American Contributions to Industrial Chemistry	SAMUEL P. SADTLER,	199
The Development in the United States of the Manufacture of Products Derived from Coal	H. W. JORDAN,	209
Notes on a New Process of Bleaching	S. F. PECKHAM,	219
Lutes and Cements	S. S. SADTLER,	223
The Design and Operation of Ozone Water Purification Systems	SHEPPARD T. POWELL	233
Changes in the Volume and Specific Gravity of Linseed Oil Films on Drying	G. W. THOMPSON,	251
The Utilization of Wood Waste	ARTHUR D. LITTLE,	257
The Production of Ammonia from Cyanamid	W. S. LANDIS,	267
The Constitution		279
Code of Ethics		287
Officers and Committees for 1916		291
List of Members August, 1916		294
Index		305

TRANSACTIONS OF THE AMERICAN INSTITUTE OF CHEMICAL ENGINEERS.

RESOURCES AND POSSIBILITIES OF CHEMICAL INDUSTRY IN THE SOUTHWEST

By EDGAR BARUCH

Read at the San Francisco Meeting, August 26, 1914

If what follows sounds like a typical California booster programme, kindly grant me your forbearance, for you yourselves are partially to blame in offering an occasion to a native to talk about the opportunities and advantages of his own country. Further, I must crave the indulgence of Californians present for the glaring deficiencies of this hasty outline of subjects any one of which could hardly be fairly treated in the time allotted.

In outlining the task of attempting to convey to you in less than an hour, even a faint idea of the illimitable resources and possibilities of the "Southwest," it seemed essential to curtail from the very start the boundaries of the discussion.

Generally the "Southwest" is designated as that portion of the United States lying west of the crest of the Rocky Mountains and south of the northern line of California, Nevada and Utah, a territory which includes all of these states as well as all of Arizona and portions of Colorado and New Mexico. The facts of this paper have been purposely limited to the confines of California and Nevada, though enthusiastic Californians might have suggested that the single name California be substituted for the "Southwest." Some "Native Sons of the Golden West" often state that were California to be severed from this continent or even the rest of the world by a cataclysm of nature, the state would in no way lack any of the natural resources which are the basis of the comforts and luxuries of modern civilized communities.

This statement like many others emanating from California is difficult for strangers to believe, but is in reality not far from the actual truth. The following considerations may help to bear out this fact.

Geographically the northern boundary of California and Nevada extends 525 miles on Lat. 42° North; the eastern side of Nevada is on the 114th West Meridian; the southern line of California is about 32° South Lat.; and the western boundary extends along more than 800 miles of the shores of the Pacific Ocean in a general northwesterly by southeasterly direction. California alone curiously covers the extreme distances both north and south and east and west, and these are so great that they have an important bearing not only on great variations in climate, but also in transportation problems and the development of resources.

California has an area of 158,000 square miles and a population, according to the 1910 census, of 2,377,000 (not counting the tourists). Nevada has an area of nearly 111,000 square miles and only 81,875 population. Just for comparison note that the combined areas, 269,000 square miles, are greater by more than 25 per cent than the total area of France with its 40,000,000 population, or Germany with its slightly greater area and 65,000,000 people, while California and Nevada have a combined population of only approximately 2,500,000, of which about half are rather closely congregated in comparatively small areas in the vicinities of San Francisco and Los Angeles.

Of course the surface areas of California and Nevada are not comparable with those of France and Germany in the ability of those countries to support a large population per square mile, for not much more than one-third of the area of California is arable, about one-third is mountainous (though largely covered with timber) and the rest is desert, while almost the entire state of Nevada is a barren waste of desolate desert and parched mountain ranges on which even jack rabbits and coyotes cull but the leanest pickings of a meager existence.

The rainfall varies from almost nothing in the desert regions to 50 and 60 inches per annum in the northwestern counties of California. With but few local exceptions the climate is divided into a short wet period and a relatively long dry spell, but the large streams of central and northern California flow the entire year, fed by the everlasting snows of the high Sierras.

In California there are two great mountain ranges, the Coast

Range Mountains paralleling the entire coast and the Sierra Nevada Range which runs from Shasta in the north to Tehachapi in the south. The Sierras, well above 10,000 feet in altitude, run at a greater continuous unbroken height than the Rocky Mountains. They culminate in Mount Whitney at 14,502 feet, the highest point in the United States outside of Alaska, and from this point, but for low intervening ranges 8500 feet in height, it would be possible to look down into the lowest region of this continent, the floor of Death Valley, several hundred feet below sea level.

In the upbuilding and subsequent faulting of the continent the mountains, particularly the Sierras, were left with very abrupt eastern fasures and relatively gentle western slopes. This accounts for the general direction of nearly all California mountain streams being westerly; there are practically no large streams running towards the east. Between the great mountain ranges in California there is an immense valley, which converges towards its center to empty its drainage into the ocean through the "Golden Gate," the only low break in the Coast Range. The two branches of this valley, the Sacramento and the San Joaquin, are traversed by rivers of the same names which flow together in the delta region east of San Francisco Bay. The great valleys have been built up of thousands of feet of mountain erosion and owing to the variations in climate, ample water on the eastern sides, and rich soils, are highly fertile and adaptable to almost every conceivable crop. The coastal valleys are relatively small, but numerous, and conform in various positions between the spurs and ridges of the more or less irregular minor ranges. Those most important are Eureka, Santa Rosa, Santa Clara, Pajaro, Santa Maria, Santa Barbara, Ventura, the Los Angeles and San Diego and their tributary valleys and Imperial Valley. Owens Valley running north and south takes the small eastern run-off of the Sierras which for ages collected in the basin of Owens Lake. This water is now being partially tapped from the Owens River as a source of water supply for Los Angeles City, by the great project of which you have all undoubtedly heard.

From a glance at the map you will note that the great desert of the state of Nevada is literally interlaced with one continual succession of short mountain ranges, nearly all of which run north and south. In between these ranges, owing to the lack of water, the floors of the valleys are rather steeply sloping with the detritus

of boulders, rocks and sand of the slowly decomposing surrounding hills. In the entire state there is not one stream worthy of mention whose run-off ever reaches the ocean. In consequence such torrential storms as at times visit local districts, drain rapidly into pocketed basins or valleys, of which there are hundreds, where they ultimately evaporate in the form of dry lakes of concentrated alkali salts. These same conditions occur in like manner in the southern desert region of California, where the saline deposits have been of more interest for no other reason than their more favorable geographic location.

Having thus shown you in the most cursory manner a few of the facial features of the country let us attempt to trace therefrom a few of the facts which have made these characteristics of such great value as natural resources of inestimable wealth.

There are harbors all the way down the coast from Eureka to San Diego. San Francisco possesses probably the most wonderful harbor in the world, large enough to shelter every vessel of the globe (even before the Germans and the English started their efforts to put ships at the bottom of the sea). There are splendid open roadsteads at Fort Bragg, Monterey, San Luis Obispo, Santa Barbara, Santa Monica and Redondo and well protected harbors at San Pedro and San Diego.

The San Joaquin and Sacramento Rivers are both open to transportation for several hundred miles.

Streams like the Trinity and Eel Rivers and the perpetually snow-fed streams of the Sierras, the Feather, Butte, American, Merced, Kings and Kern Rivers, as well as a dozen others, are some of them already furnishing hundreds of thousands of electrical horsepower and are capable of supplying millions more.

The ribbed and scarred mountains besides being the source of water power and timber, offer an infinite array of minerals.

The "49ers" in their mad scramble for gold overlooked most other metals, minerals and resources. It was not until the discovery of the Comstock Lode that attention was devoted to the silver lead ores and nearly fifty years elapsed before any copper was produced from the Shasta district, and later in Nevada at Ely, Ludwig and other places. There were numerous reasons for the slow progress in the development of the mineral resources: transportation facilities were lacking; the technique of handling

and milling ores was crude; cyaniding was unknown, which made only placer and free milling gold ores of high value available; water power could only be utilized from wooden wheels at dam sites, and steam power by the expensive use of wood as fuel in timbered districts. Because coal, oil and gas were unknown smelters did not exist and processes for handling complex ores have only been developed during comparatively recent years, by the concerted efforts of the chemists with the mining engineers—efforts which are still proceeding with unflagging energy and are daily budding into new and successful processes and methods. Think, for example, of the development of the Pelton and turbine wheels for power, the marvelous evolution of the dredges, the economies of the cyanide processes, the Cottrell improvements for obviating smelter fumes and the new processes for leaching copper ores.

The California gold production since 1850 has amounted to $1,600,000,000 and is still nearly $20,000,000 per annum. Nevada has produced $400,000,000 and now furnishes $12,000,000 gold annually. The low prices of lead and silver put such a quietus on the production of these metals that their important deposits have been all but forgotten.

California and Nevada still produce more than 85 per cent of the quicksilver from the United States, about 15,000 to 18,000 75-pound flasks per year.

Platinum has long been found in the sluicing and dredging operations on the Trinity River and northern streams of the Sierras, but no consistent efforts were ever made to trace the occurrences to their sources. Quite recently some enormously rich deposits have been found in conjunction with zinc, in the Good Springs country in southern Nevada. Pockets of ores have been found running as high as $11,000 platinum, palladium and gold to the ton. The fact that the ore looks like a rusty clay probably accounts for ignorant prospectors having tramped over the ground for many years without cognizance of the wealth beneath their feet.

The zinc regions thus far known seem to be fairly well concentrated from Ivanpah to Good Springs. The occurrences are in the form of both calamine and sphalerite.

Tin was developed from cassiterite ores at Temescal in Riverside County some years ago, but the deposits are now lying idle.

Antimony has been long known, but shipments have only recently been started and a smelter is now in operation at San Pedro.

Bismuth has been found in veins south of Banning, and arsenic occurs frequently with gold ores on the Mother Lode. Chrome is found in large quantities on the western slopes of the southern Sierras.

Manganese is almost of common occurrence. The largest deposits are in the Coast Range mountains of Tehema and Mendocino Counties, at Tesla in Alameda County and in the Chocolate Mountains of Riverside County.

A Los Angeles engineer recently published a most illuminating article on the iron deposits of southern California in which he shows that by the most conservative estimates there are over 200,000,000 tons of iron ores available in the Providence, Eagle and Kingston mountains, all adjacent to railroads. The deposits average 64 per cent iron content against 55 per cent ores from the Mesaba Range and there are fewer impurities, such as phosphorus, sulphur and silica. Is it not remarkable that with a yearly consumption of 900,000 tons of steel, and with limestone, fuel and nearby coke available, that these deposits remain untouched?

Not far distant from the iron are manganese and the only working deposits in the United States of tungsten. The electric smelting of iron at Heroult proved too expensive to be practical and the plants have been given over to the production of ferromanganese. We have thus far badly neglected our opportunities of furnishing this country with high grade steels.

The extent of the limestone formations even in the southern sections, alone, almost beggar description. At Sloan, Nevada, range after range of mountains stand hundreds of feet above the floor of the desert, solid unbroken masses of high-grade limestone. At many other points westward all the way to the coast there are hundreds of millions of tons of exposed limerock. Big cement plants are to be found at Oro Grande, Colton and Riverside, also in the north at Santa Cruz, Napa Junction and Cement, while lime deposits occur in the mountains all the way to the northern boundaries of the state.

Relatively, magnesite is of but small occurrence, though California is the only state in the Union producing it. There is a small deposit at Winchester, a larger occurrence near Mojave and mines are now being worked near Fresno, at Red Mountain and in Sonoma and Napa Counties.

Kaolin, china porcelain and pottery clays are found at Ione in Amador County and Placer County with feldspar and silica not far distant, yet California imports yearly $300,000 worth of china and porcelain from the East. Brick and tile clays occur in river bottom lands in sections too numerous to mention. From the dark heavy clay soils of the ground on which they squatted the early Spanish and Mexican settlers made sun-dried bricks, from which they built their adobe huts.

Silica in the form of quartz can be obtained almost everywhere and there are fine deposits of white silica for paints and glass-sands in Nevada.

Sulphur was mined for many years in Humboldt County, Nevada, and fairly large occurrences are just south of Goldfield, while a very large new discovery has just been reported from Kern County.

Most of the world's supply of borax comes from California, from the great Borax Smith mines in Death Valley and more recently from the Ventura County deposits of colemanite.

The deserts furnish gypsum, talc, celestite, baryte and salt in profuse abundance and the dry lakes contain untold millions of tons of soda in the form of both carbonates and sulphates. At Searles Lake of unfortunate exploitation, the American Trona Corporation spent more than $500,000 for a railroad before they had so much as evolved a process for working their raw materials. They planned to recover from the lake brines primarily potash, also sodium carbonate, sodium bicarbonate, sodium sulphate and borax. Many of the sinks of Nevada contain considerable amounts of potash; and much harmful exploitation and ill-directed effort has been expended trying to obtain potash from the sea weeds and kelps of the coast, from which the companies have hoped to recover iodine as well as many organic materials.

Throughout the two states there are small or sporadic deposits of fluorite, bauxite, molybdenite, nitre, graphite, mica, asbestos, jasper, ochre, pyrites and alum, not to mention a hundred other less important minerals.

Mineral waters and springs of all descriptions, hot and cold, mud, sulphur, soda, salt and lithia are to be found.

San Diego County furnishes us with the lithium salts of lepidolite from Pala, and from the same region are derived the semi-precious gems of tourmaline, aquamarine and kunzite. Elsewhere

we obtain moonstones, garnets, tourquoise, onyx, opal, sardonyx, chrysoprase, catseyes, variscite, rhodenite, californite, beryls, topazes, jades, abalone and pearls, even sapphires, and not to be behind Arkansas occasional diamonds are noted.

Fuller's earth, little of which has been utilized, occurs in Nevada and in the San Joaquin Basin.

There are numerous deposits of infusorial or diatomaceous earth in both California and Nevada. Probably the finest and largest deposit in the world is at Lompoc in Santa Barbara County. Through the efforts of the owners and their research chemists the value of their product has been demonstrated in many different industries. According to the specific gravity and purity of the material it is used in such diverse fields as the manufacture of sugar, edible fats, light brick, as an insulating medium, etc., some forty patents having been applied for or issued within the last few years covering the applications of their products to new uses. This is only one indication of the possibilities of well-directed chemical industry in the use of heretofore disregarded material.

We have an abundance of building materials such as slates, rhyolites, trachytes, volcanic tufas, obsidianites and basalts. Marbles are plentiful but quarries near existing railroads generally appear to be badly faulted and shattered, though the main difficulties in obtaining good slabs can usually be attributed to the ignorance with which our western deposits have been worked. Excellent varieties of colored, veined marbles are found at Carrara, Nevada, and green malapi conglomerates are obtained from near Barstow. All forms and colors of granites and sandstones are available of which you have seen many beautiful examples in the buildings of Los Angeles and San Francisco. Our cities need not go as far as Rome went for their paving blocks, macadams, rubbles, gravels, sands and building materials.

In some of the valley regions there are large deposits of peats. Lignites and coals occur in the Coast Range Mountains. But of far more vast importance to chemical industry have been the discoveries and development of petroleum oils and natural gas during the last twenty years. With a production of 7,000,000 to 8,000,000 barrels of crude oil per month no one need longer worry about any possible lack of fuel supply for our industries. California has at this writing approximately 55,000,000 barrels of oil in storage above ground. Since the inception of the industry in 1890 approx-

imately 750,000,000 barrels have been produced and nearly 90 per cent of this amount within the last ten years.

We are refining as much of our oil as the markets will take and make casing head gas, gasoline, kerosene, distillates, lubricants, and asphalts, but in view of the enormous sources of hydro electric energy available for power it would appear that in burning our surplus oil we are practicing a criminal wastage of our resources for which we can hardly expect our descendants to forgive us. We have indeed been unwise as well as profligate with our heritage of natural wealth, to an extent from which we of the younger generation and our immediate children will suffer the effects. This condition applies particularly to our careless even willful wastage of natural gas encountered in drilling for oil and which we in our haste for the nearest dollar, have allowed to escape us to the cost and comfort of future generations. To be sure we are now beginning to pipe some of the excess gas from the wells to the cities, but distances in this country are great, investments large and subsequent prices for the gas are high.

Water gas from crude oil is the basis of most of our artificial supply. The only efforts made to utilize the by-products of this industry are in the making of carbon briquettes; the naphthalines, pitches and tars are all wasted.

The increased use of direct combustion oil engines of the Diesel or semi-Diesel type should do much to effect economies in the consumption of oil fuels.

The shortness of my time limits more than the mere mention of such well-established industries allied to the mineral resources as acid and powder manufacture, the production of fertilizers, glass and heavy chemicals.

With this hop, skip and a jump I fear that you have gained only a very faint conception of the extent and variety of our mineral products, but suffice it to say that of these materials California alone produced $103,000,000 worth in the year 1914.

Agriculturally the resources of Nevada are too small to warrant attention at this time, but California more than makes amends for the deficiency.

The great valleys which twenty years ago supplied little more than grain and cattle are to-day undergoing constant transition towards more intensive farming and diversified crops. Wheat,

barley, oats and corn are still grown in enormous quantities, and now-a-days large crops of rice, on what were formerly called goose or bad lands. Hops for the brewing industries occupy much of the bottom areas of the Sacramento basin. One will find vineyards all the way from Red Bluff in the north to Bakersfield in the south, with the attendant industries of raisin growing, wine making and sometimes the production of argols. Interspersed with the vineyards you will see orchards of cherries, almonds, peaches, pears, apricots and prunes. Asparagus, potatoes and vegetables of all descriptions are grown on the river islands and deltas. The valley foothills grow olives, lemons, oranges and grape fruit and in the higher altitudes the best of apples.

South of San Francisco, along the coastal valleys as far down as San Juan Capistrano approximately 125,000 acres of sugar beets are planted annually, which yield about 500,000,000 pounds of sugar, an amount 2½ times in excess of the needs of our own population, not counting the equally large output of Hawaiian sugars from the two refineries on San Francisco Bay. Chemically and technically the beet sugar industry has reached a high state of perfection though there are still many opportunities for improvements, particularly along the line of investigative agricultural chemistry and in the utilization of the waste products. The plants which have only molasses as an end product sell their material to either alfalfa-meal mills or to the distilleries for the production of alcohol. Those plants which have installations of the Steffens recovery process, in general, still send their waste waters, which contain distinctly valuable amounts of potash and nitrogen, to the sewers. In one or two instances these waters are pumped on to the fields as fertilizer. Other plants are making efforts to concentrate their waste waters in conjunction with their lime cakes for the production of marketable fertilizers. About 3.5 tons of potash have heretofore gone to waste with every 1000 tons of beets worked.

The southern valleys, generally subject to fogs during the summer months, are well adapted and produce, in addition to sugar beets, large crops of beans, walnuts and olives. A recent improvement in the olive industry is a process for extracting tannic acid, drying bruised fruit—or mincing the meat, boiling it in its own oil we grow peanuts and make the oil and butter therefrom.

The citrus products for which Southern California is so well known are grown in the foothills and the semi-high regions where

the orchards are least affected by the frosts. It is only of recent years that much attention has been paid to the possibilities of utilizing the fruits to the fullest advantage, particularly the so-called culled fruits. The associations of growers are maintaining separate laboratories, besides the special government stations, attempting to work out processes for the production of citric acid, oils of orange and lemon, citron, candied peel, marmalade, orange butter, orange wine and orange syrups.

The new farming districts of Imperial Valley produce alfalfa, cattle and cantaloupes. The finest grades of long staple cotton are grown in this district and the cotton seed oil and cake industry is naturally following in the wake. A fact not generally known is that California is producing annually about 600,000 pounds of Turkish cigarette tobacco.

The fishing and canning industries along the coast are worthy of special mention. Sardines from San Pedro have for many years been boiled in California olive oil and put on the market in French-looking cans. But an industry all our own, established at the same point, is the production of canned tuna. Salmon have been caught in the Sacramento and the northern coast streams since the beginning of our history. Oysters, the small varieties, quite different from the large eastern type, are found in the bay regions.

The gradual encroachment of orchards and intensive farming on the old princely estates of the land barons who formerly owned 40,000 to 60,000 acre tracts has also demoralized the old time cattle ranches of the low lands. The grazing grounds have been gradually driven further back into the hills and mountains, and only when the grass becomes short or the cattle are to be fattened for the markets are they herded into the valleys for alfalfa, grass or grain feeding. Dried beet pulp is attracting considerable attention and the entire output of three of the southern beet sugar factories is either steam or kiln dried and sacked for dairy fodder; other mills pump the extracted beet slices to silos where the water drains off in part and the remainder, after souring, is highly valued for cattle fattening.

Our packing house industries are, of course, diminutive compared to those of the middle west, none the less we have our tanneries, soap works and other allied branches of this work. It is, however, worthy of note that our hides all go east to be made into

shoes which have to make another trip across the continent for our use. The majority of our wool and cotton follows the same course. The only textile mills we have weave cotton bags and canvas.

Other textiles such as jute, sisal, hemp and flax, though possible of development from the standpoint of soil and climate are ignored on account of our inability to compete with the cheap labor of the tropics. Tropical products of greater market value such as dates and avocadoes (the alligator pear) are achieving a well-merited success.

Some attention has been given to the utilization of the natural desert products as the fibers of the yuccas and the utilization of cactus for crystallized candies. There are in addition thousands of natural wild herbs and plants of value, but few of which, such as yerba santa, cascara sagrada and oak bark for tanning, receive attention, while we have entirely overlooked possibilities for the production of oils from other plants such as oil of bay, oil of mustard, castor oil, oil of peppermint, sage oils, oil of eucalyptus and oil of cedar. One of the large English essential oil companies has been so much interested in the application and uses of the natural flora that they have had men in the field investigating the possibilities, quietly, for several years past.

There are 430 flower farms in this state and though the climate and soil conditions in Southern California and along the coast all the way north as far as Santa Rosa are fully as good as along the Riviera and the Italian shores of the Mediterranean—we do not possess the labor conditions of the European countries and hence are entirely lacking in a perfumery industry. The time will undoubtedly come when California will supply this continent with its full requirements of oil of geranium, bay, lavendar, thyme and rose in addition to the long list of the essences and perfumes which can be obtained so readily from the infinite variety of flowers which bloom along these shores.

California dried and canned fruits are sold the world over. Glazed and crystallized fruits are well established industries and under new processes fruits, violets, rosebuds, orange blossoms and other flowers are candied and the original shape and coloring perfectly preserved. If you have not tasted California sagebrush and orange-blossom honey, do so—for it is a product not found elsewhere.

The California mountains are covered with millions of acres of

fine timber, redwood, cedar, yellow and sugar pine, spruce, firs and oak. The greater part of the timber is used as sawn lumber, shakes, shingles and railroad ties. At Floriston on the Truckee River there is a big paper mill, and the Diamond Match Company have extensive interests in and around Sterling and a large match plant at Chico. We lack entirely destructive distillation processes and methods of utilizing sawdust and stumpage.

You have probably already been wondering why this brief catalogue of our resources and industries is so lengthy. I have been trying to convince you with a short survey that Californians can make good their boast that they lack no resources to make and supply them with all necessary physical comforts. Nature was probably never more bountiful to any country than to this Golden West. We possess all the resources for great industries based on electro-chemical, metallurgical, mineralogical, agricultural, horticultural, husbandry and forestry pursuits.

Why have these not been more firmly established and grown to greater extent? Why do we ship our crude products to the East and foreign countries for fabrication without even taking them through the gates of our cities, to have them shipped back to us in only slightly altered form for our consumption? Why are our harbors only transient points for all the riches of the tropics and the Orient? Why have we been so slow to realize and to utilize to the fullest extent the resources and to materialize into tangible assets the long dormant possibilities of our western kingdom?

The reasons are numerous. View our "splendid isolation" with the vast Pacific on one side of us, high mountains and broad deserts on the other, an almost barren uninhabited peninsula on the south and long reaches to civilization on the north. There are only four mountain outlets from California, ranging from nearly 4000 to 7000 feet in altitude. Bear in mind that we are more than 3000 miles from the eastern seaboard, 2000 miles from the center of population in this country; that it takes six days to reach Hawaii, the nearest islands of the Pacific, and three weeks to Japan, China or the Philippines, by fast mail boats.

Our "Empire" is traversed by only three trunk line railways, with but few branch and spur line ramifications into the surrounding territories, and these lines largely parallel each other. In consequence, ore and timber deposits, with the possible exception of precious metals, are almost valueless unless by chance they lie practically

adjacent to existing transportation. It is impossible to haul salt, gypsum, talc, magnesite, soda, potash, chrome or manganese from 10 to 50 miles over desert or mountain roads with any hope of putting such products on even the local markets at a profit. The first question asked of the prospector is "How far are you from the railroad?" Though we still have amongst our population many hopeful prospectors, sturdy mountaineers and tanned desert rats, they have mostly learned that, excepting for gold, they cannot wander far from the iron rails. In consequence there are still great undiscovered, almost virgin regions in both California and Nevada.

Irrespective of long hauls to the railroads we have had much to contend with from the railroads themselves. No better picture of this phase of our development has ever been penned than by Frank Norris in the "Octopus," in which he vividly describes the bitter hatred of the California pioneers for the Southern Pacific Railroad of the days of Collis P. Huntington. Though the old railroad tyrant has been long dead, they failed to bury all railroad abuses with him. However, since the Harriman régime, the Southern Pacific Railroad has improved wonderfully and the competition of the Santa Fe and the Western Pacific and the State and Interstate Railroad Commissions have done much to better conditions.

I am informed that in the East it is possible generally to figure 3½ mills per ton mile on railroad haul for ores. The lowest rates of which I am aware in this county are 5 mills per ton mile on certain sections of the Santa Fe. The beet sugar people pay 7 mills per ton mile for 70,000 tons of rock per annum over 197 miles of track. Recently I had some cheap ores (silica) to be moved 200 miles in Nevada. The first quotations were $15.90 per ton and it took much coercion and many weeks of voluminous correspondence ultimately to obtain a rate of $3.90. If you desired to ship desert sand or ordinary rock from Nevada 400 miles to Los Angeles you would have to pay $4 per ton freight (10 mills per ton mile); to San Francisco, 500 miles, you would have to pay $6 or 12 mills per ton mile. The glass factories in the bay region claim that they pay only $5 per ton for Belgian sands after they have been transported 20,000 miles.

The lowest ore rates to the East via the Panama Canal are $7 per ton. Via Galveston on the Southern Pacific there is a $10 rate, but all material must be sacked. The lowest all-rail rates are $12 per ton. This is sort of a blanket rate to the majority of the railroad

centers throughout the country. It costs $12 a ton to ship low value ores to New York, Boston, Chicago, St. Louis, Denver or Salt Lake City, and as anomalous as it may sound, you might have to pay anywhere from $15 to $18 per ton if you wanted to stop your shipment at any point before it reached even Salt Lake City, the nearest terminus.

Our labor problems present many difficulties. With the total exclusion of the Chinese and the restrictions on Japanese, Hindoo and Mexican laborers we have discouraged and retarded many big enterprises. We are in need of foreign labor, a moderate number of thrifty Chinese or busy Japs would be of decided advantage to this country. We do not need Greek and Neapolitan fruit venders or organ grinders to crowd our cities, but we do need fruit pickers and mill workers.

Life in the rural and mountain regions is generally most attractive. Hunting and fishing still abound and there are good roads thereto in almost every section.

The city conditions are not much different from other parts of the United States. San Francisco as a world harbor is very cosmopolitan,—a small New York. For many years it has been burdened like the old man of the sea with Unionism and labor troubles, yet see with what majesty she recovered from her devastating ruins. Los Angeles, a very moral town, is the next to the last abiding place of most of the successful farmers of the Middle West and many other people who can raise the cash to pay the railroad fare to what they think is a land of ease and indolence. The chief industries of this branch of the population are real estate and insurance.

I trust that I may have conveyed to you that we produce a far greater quantity of raw products, fruits, sugars, cereals, textiles, timbers, fuels and minerals than the people within our own borders can consume. The difficulties which lie in the way of and hinder more rapid development are the lack of sufficient and reasonably priced transportation facilities for getting our products to markets. The sparsely settled country and the lack of population particularly of working classes is the cause not only of restricted local markets but also of high labor costs for all products. The newness of the country has called for immense outlays of capital for development purposes, but investments in our big industries seem to be attractive to even foreign money, as is witnessed by the interests of the Dutch Shell Oil Company and the General Petroleum Company in

our oil resources and there is also much foreign capital invested in our copper and gold mines. We still need vast sums to help sane, rational development,—but we trust that we shall no longer be oppressed with the scandalous exploitation schemes of scoundrelly promoters.

There are at present more pregnant opportunities for the development of resources than in the days of the pioneers of '49. We are only in need of much strong, honest effort and staunch capital to back it to make this one of the richest countries of the world.

It is frequently said that when one once visits California the longing to return never ceases until one comes back to live. We hope *you* have caught the lure of the "Golden West" and that we will some day see all of you chemists and engineers, you men who accomplish things, back amongst us in the near future, helping us with your hands and brains to change our possibilities into realities, and helping us to put to the best uses of mankind our great resources.

DISCUSSION.

The CHAIRMAN: The paper is open for discussion. I am sure that some of you will have questions to ask of Mr. Baruch and he would be glad to answer them.

Sec. OLSEN: We certainly have been pleased with the enthusiasm with which Mr. Baruch has exploited the industries and possibilities of California. I was rather pleased to hear Mr. Baruch say that one of the difficulties was the scarcity of labor, and also I was pleased to hear Mr. Baruch say that the exclusion of labor was one of the mistakes of the coast. I don't know whether he emphasized as strongly as he might the handicap of lack of population. Perhaps most of you know that the great majority, perhaps three-fourths of the chemical industries of the country are centered in the East around New York, Philadelphia, and Boston where factories may be found by the dozen and by the hundred.

Now, there are two or possibly three, influences in that region which it seems to me, bring about that condition. They are density of population, which gives a market. That solves the railroad question which was brought out so vividly. You don't have to have a haul of three thousand miles to get to your market, and in California if the population were ten or twenty million instead of two and one-

half million there would be a local market which would absorb the products of the factories, and therefore the railroad problem would disappear.

In the second place the labor in the East is plentiful, coming from Europe, and that has been permitted to come in. Now it seems to me that there is one thing which the United States has solved to a certain extent and that is the assimilation and utilization of labor, and it seems to me the Pacific Coast ought to attack the problem of assimilation and utilization of such labor as they can get, and that this is one of the chief problems here.

Another point Mr. Baruch brought out was the need of capital, but in his paper he also stated and gave as an illustration the attempt to produce potash from Searles Lake, and stated that three million dollars was expended in that industry. If this paper is designed to attract capital to California that statement should be cut out or should be modified or explained. I think that this is an outstanding, important question which should be asked with reference to this paper and it was not sufficiently answered by Mr. Baruch. I have no doubt he can tell us why, after the expenditure of three million dollars, that project was a failure. I should like to hear an answer to that question. I would like to know why three million dollars, which seems an ample sum, and it is a good deal of money, expended in that way was not sufficient to start a profitable industry.

He told us with reference to the kelp industry, of which we have heard a great deal, that that has been a failure because they looked for by-products instead of the main product. That does not seem to me to be a complete answer. It would seem to me that the attempt to produce by-products was an attempt in the right direction. I assume that the potash was to be gotten as well as the by-products and that therefore it started as a complete industry getting main products and by-products, and so the entire situation was attempted at least to be covered.

I would like to ask one more question and that is with reference to the platinum deposits which he mentioned, that is the high-grade platinum ore which has been discovered. I would like more information as to those particular deposits, whether there is plenty of the ore and whether there is a possibility of its being worked. The chemists and the chemical engineers are all interested in that situation and interested to know if there are prospects of con-

siderable platinum and if the deposits are in such shape that they can be profitably worked.

Mr. BARUCH: To start from the east question; you asked about platinum. The platinum deposits are being worked. The owners are working them and developing them quite rapidly, as rapidly as mine work can proceed. The claims are pretty well taken up but, as stated in the paper, the deposits of platinum are rather pockety. The platinum is found with palladium and zinc. You will find a very good article on the form of the occurrences in the March, 1915, number of the *Oil and Mining Bulletin,* issued by the Los Angeles Chamber of Mines and Oil, which covers the subject very fully.

Referring to the Searles Lake proposition, I am afraid that explanation would call for public criticism of a corporation, which I do not think desirable. The American Trona Corporation made a well-merited attempt to help develop our resources. I don't know that there is any further answer to your question than that.

Sec. OLSEN: I would like to know what mistakes were made or what they did not do which they should have done. It is a very important thing to know why that development failed.

Mr. BARUCH: It calls, as I say, for public criticism of a well-intentioned, but probably poorly-advised corporation. The management apparently had ample money. It was financed by the Goldfields Company, Ltd., who have unlimited funds at their disposal. It was only a side issue for them. They picked out certain men to take charge of their processes and apparently made a very unfortunate choice of the men; men who made claims of having solved their problems before they were engaged for their work and large sums of money were expended to develop the processes, which proved an absolute failure.

Sec. OLSEN: That is, it was the technical end of it that failed?

Mr. BARUCH: The technical end of it was an absolute failure.

Prof. STILLMAN: Would this refer, Mr. Baruch, to the refrigerating machinery which I understand they are installing?

Mr. BARUCH: No, I am not discussing their present methods at all, only their previous efforts, those which were made during the past three years, up to last winter when they shut down. Their plant is at present entirely dismantled. I believe they have only a watchman and perhaps one or two chemists still analyzing brines. They had at one time a force of twelve analysts working continually

day and night, who, according to hearsay, did little but analyze the deposits.

Prof. STILLMAN: If I am not misinformed they are now engaged in active operations on a new plan for the recovery of potash and so forth.

Mr. BARUCH: You don't mean that they are operating?

Prof. STILLMAN: I mean they are getting ready.

Mr. BARUCH: Getting ready, yes. So I understand. I am personally not associated with the company and I don't know the inside details and I would naturally prefer to refrain from open criticism of them. It is none of my business and we are not in a position to criticise work when we are not entirely acquainted with it. As to the other question you asked?

Sec. OLSEN: I think you answered my two important questions.

Mr. J. W. BECKMAN (Berkeley): I want to take issue with Mr. Baruch. I don't think he was quite fair to California. He said that if we were isolated altogether from the rest of the world we could produce everything that we needed. Amongst other things, we need steel and iron, and then he says we have to go to Utah for our coke. It is a well-known fact, at least I think it is well established that iron production to-day has practically not changed since it was first originated in blast furnace excepting for the dry blast, so coke at the present time is considered one of the essentials and was always considered one of the essentials.

Now California produces oil and there is no reason in the world why the carbon and hydrogen present in the oil should not be utilized in the production of iron ore. It really comes down to a mechanical process and that to my mind is one of the greatest problems that to-day faces California, the application of the hydrogen and the carbon we have to-day in our oils in suitable shape.

Then another thing that I didn't think Mr. Baruch pointed out was the market possibilities of California. He gave us here quite a number of interesting statistics regarding trade which really eliminates the possibility of looking outside of the small section of California for our markets. We have heavy freight rates and to begin with our manufacturing cost is a little bit higher here on account of the cost of labor than in the East and so we are limited to the population along the coast, which approximately amounts to five million people, but I believe that there is a situation here in California to-day that is not equaled in any place in the world for

a market. I am eliminating absolutely the East. We are perfectly willing in California to let the East take care of itself. They will be able to attend to their own affairs and supply themselves. We are looking west, that is, to the far East, where lies over half the world's population in a country facing the Pacific Coast. It may be legitimately said that those people are a more or less primitive people and consequently the demand for a civilized—I don't have to say civilized, regulated nation's product is comparatively small; but it can be shown from statistics from the Philippine Islands that while they were under Spanish rule, which really was primitive, they imported to the Philippine Islands thirteen million dollars' worth of stuff and the 1914 statistics show they imported fifty-six million dollars' worth of stuff, more than four times as much materials from an organized nation than they imported before. We have half a million population and facing us are nations like Japan and China, and China trying very vigorously to get regulated, if I may use that word, and consequently these nations need our products. We have an open market with that section of the world. We have absolutely that market open to ourselves. I think that is a fact that Mr. Baruch didn't point out, to emphasize the market possibilities for the industries on this coast.

Mr. Baruch: In answer to that last criticism, of course there are market possibilities here and in the Orient, but we will have to build up our own merchant marine, which this country needs very badly, before we will really be in a position to convey our products to the great markets of the East. We had a nucleus of a merchant marine in the Pacific Mail boats but by very ill-advised legislation we have put that company out of business entirely. They have sold their boats, I understand, right recently to the Atlantic Transport Company. It is essential that we develop the methods of getting our goods to market, whether it be by more reasonable freight rates or whether it be by our merchant marine. It is up to us to solve those problems.

As to the first criticism regarding coke, I mentioned merely in connection with coke that cheap coke was available from Utah. As a matter of fact we do possess coking coals in the coast range mountains but they are not fully developed at the present time and they are far removed from the railroad. I think that statement of mine that we do possess the actual necessities still holds but I merely mentioned that we could at the present time, without develop-

ing our own coking coals, install large iron works in this country to supply our own needs at a cheaper price by using Utah coke.

Mr. BECKMAN: As I understand the California coal situation, the lignite coals are all of low grade containing up to 30 per cent of ash, which makes it economically impossible to utilize them.

Mr. BARUCH: The utilization of any coal running as high as that in ash would be impracticable even for fuel purposes. We have some coals in the coast range mountains which would not run as high as that.

Mr. BECKMAN: I am afraid Mr. Baruch takes the wrong attitude in regard to our markets. I think we have here a wonderful opportunity. After special investigation I find that the Japanese are willing to carry caustic soda from this coast for $5 a ton to Japan. Caustic soda was selling here for $45 a ton and it was selling for $60 and more in Japan which gives an enormous margin. That is free on board this harbor. It is unfortunate we haven't an American merchant marine but we don't need one absolutely as we can use the Japanese ships.

Mr. BARUCH: Without independent or competitive transportation you are always at the mercy of other people; in fact, that lack has been a great drawback to the development of this country. For instance, at the present time there are innumerable opportunities for the development of mines, also as you say, for caustic soda and carbonate of soda and many other things. There is hardly a day goes by but that some new proposition comes up for the development of western projects. We don't take hold of them and the reason is that we don't want to put ourselves in jeopardy of having our heads cut off at any moment by someone who can hold us at their mercy. We are far behind in the development of our resources, but the day will come when they will be developed, though this will not be until there is ample competition in transportation so that we will not be at the mercy of any country or any company who wishes to put a quietus on the development of any special industry. Take manganese for example. Recently many interesting propositions for the development of manganese have been presented to me. But these mean to begin with, the installation of probably sixty or seventy-five thousand dollars' worth of automobile trucks or the expenditure of several hundred thousand dollars for a railroad to get material to a shipping point, from where to our own eastern consumers it is essential to pay from $9 to $12 a ton freight on crude

ores, in addition to which we must figure that we then have to face the competition of the entire world, fed and supplied by cheap labor and cheap transportation. Only very bold investors or speculators dare risk large sums with such conditions confronting them, for it must be borne in mind that present high prices are only due to the artificial stimulation of the war.

Mr. BECKMAN: Of course, we are living now under very extreme conditions and to my mind it would be exceedingly unwise business policy to go into an industry that is only to live at war prices, but we certainly hope that people will get tired of killing each other and things will return to normal conditions again. The point you make on manganese came up with me and I said "No, don't go into manganese. You can't afford to build up an industry to-day that will fall down to-morrow."

Mr. BARUCH: While I have your attention I want to call your notice to the relative distances in this country compared with Europe. I have here a railroad map of the United States which I have spread over Europe, both approximately on the same scale. This will give an idea of the relative distances of California and Nevada and the United States compared to Europe. I have sketched in here with blue pencil California and Nevada, which will give you an idea of the relative sizes of these two states and the distances from our western coast to Chicago. The center of population of the United States is somewhere in Indiana, which is equivalent to carrying freight practically from Paris to the Ural Mountains, quite a territory; a thing which is really not tried to any extent in Europe, except for exceptionally valuable merchandise.

Mr. WEBER: I just want to state that here on the Coast there are still some things in the old régime of the Southern Pacific of demanding all the traffic will bear. In the beginning the charges were screwed up to the top notch and it has been hard, hard work on our part to get the rates down. Even with cheap coal in Alaska and Washington and Oregon, with transportation by sea, by which freight should be laid down here in San Francisco Bay at a few dollars a ton, transportation has been monopolized so that I think the industrial rate is something like $7 a ton. It is an outrage but it is impossible, it seems, to change it. It is a thing that we have to contend with here. In Alaska we have untold resources of coal right at seaboard, no transportation at all to the ship, prac-

tically, and yet laid down in San Francisco we have to pay enormous prices for it, and there is coal there suitable for all purposes.

Mr. SCHMIDT: I am just going to say one word. The impression I received from reading statistics recently, show how very misleading they very often are. If one considers the small size of California and the tremendous resources within the state one can hardly help but feel that every one who lives within the confines of the state should be wealthy, but the thought which came to my mind now was the general economic balance of it all.

In the last few years I have had occasion to spend some time in Europe, particularly in the chemical industries in Germany, and I was impressed there with the close proximity of one chemical factory to another. The waste material of one factory constitutes the raw material of another factory right at its back door. The transportation costs are practically *nil* and in addition to that, Germany has a splendid merchant marine which tapped all parts of the globe, tremendous land and water ways which convey products from one factory to any point on the globe where it was desired. We often forget that the basis of the chemical industry or any industry is the complete economic balance of the world; it doesn't depend upon the economic balance on one industry alone and that has probably been an erroneous factor in most of the calculations which recently played an important part in this country, of how we are going to obtain aniline dye. We haven't taken into consideration the general economic balance, and that is really what has held back the industries in California. If we were to establish a steel industry to-day the steel trust would put us out of business to-morrow. We cannot compete, and it will be a long process of evolution before we will play the part in the chemical industry which Germany plays to-day, and it will probably not be until we have sixty-five million people within the confines of a territory as small as California. I think that is probably the answer to why we haven't developed our resources, because if we could we would all be rich men. Some of us are trying to be such. (Applause.)

The CHAIRMAN: You must remember California is not very old yet. The process of evolution is like the criticism, why don't we produce carbonate of soda. We haven't worked at it very long. Take the iron industry, they made iron some thousands of years ago. Evolution takes years. It is a question of time. Mr. Baruch forgot one source of wealth, and he also forgot to bring out another

idea that struck me as quite apparent, the idea that California has everything a little better than any other place. We have more, and we have better things. He didn't mention the fact that we could probably make better nitric acid than they can in Norway, because the oxygen in our air is better. Another source of development that lies at our door which might be very easily gotten out is the gold out of our sea water. We made some determinations on that a short time ago and found we had some gold here in the ocean outside of the Golden Gate. That is why they call it the Golden Gate. (Laughter). We made some calculations on the gold and assumed that if we could get all the gold out of all the ocean water, everything else would be easy. All the ocean would come to California as all the people do. All we would do would be to pump that water in and extract the gold; and we are generous, we would divide it up among all the people in the world, a thousand million people in the world, everybody getting an equal share—how much would you give for your share?

Mr. ALEXANDER: You can have mine for ten cents.

The CHAIRMAN: They told us everybody in the world would have four million dollars. If we confine it to the two and one-half million people living in California think of the wealth that is at our doors! So it is everywhere. We have forgotten lots of opportunities. Dr. Olsen doesn't believe we can show him the gold in the Golden Gate. We can show you the ocean; there it is before you. (Laughter.) Now, are there any other questions?

Prof. REID: Suppose everybody in the world had four million dollars worth of gold, what would they do with it?

The CHAIRMAN: You give me the opportunity of getting the four million dollars and I will answer your question.

THE CHEMICAL EVIDENCE OF SMELTER SMOKE INJURY TO VEGETATION

By J. P. MITCHELL.

Read at the San Francisco Meeting, August 27, 1915

The injurious effect of smelter smoke on vegetation presents a problem which is serious in that it concerns the profitable development of one of the most important of the Western industries, namely the smelting of sulphide ores. It is not a new problem, but one which has become acute in recent years as a result of the development of very large smelting establishments. In fact it is an old problem which was recognized some fifty years ago in Germany, and which still remains unsolved.

This problem of smelter smoke injury is a special case of the larger subject of smoke injury in general, using the word "smoke" in its most general sense to cover all the materials which reach the atmosphere from smokestacks. Much work has been done in the broad field of city smoke, and while the realization of the deleterious effects produced by many of the solid constituents of smoke—especially soot—has resulted in both legal and technical measures being taken for their control, much less recognition has been accorded to the less conspicuous and more insidious gaseous constituents. Smelter smoke is a peculiarly obnoxious smoke in that among its common solid constituents the lead and arsenic are poisonous substances, and, where sulphide ores are smelted, the gaseous constituents, sulphur trioxide and sulphur dioxide, may be present in large amounts.

There are three great smelting districts in the Western States: the Anaconda in Montana, the Salt Lake in Utah, and the Shasta in California. In all of these very large amounts of capital have been invested in smelting plants, and each of them has a long history of litigation over the injury inflicted upon the surrounding vegetation by the smelter smoke. These histories differ widely in detail and are too intricate for recitation on this occasion, but all have certain points in common. At first the smelters were small,

the injury apparently well localized, and results negligible. With the growth of the industry came larger tonnage, higher stacks, greater volumes of smoke, and as a result, far more widespread injury in adjacent, as well as distant, forest and agricultural districts. Then followed in turn complaints of injury, damage suits, and finally injunction suits, which in some cases now threaten a complete shutting down of the smelters and serious loss of capital to investors. That the seriousness of the possible outcome of this litigation has not been exaggerated is indicated by a recent decision in a similar industry, by which a cement company which, in spite of the fact that at least 95 per cent of its relatively innocuous dust was being recovered, was enjoined from operation as long as it discharged any dust whatsoever from its stacks.

The constituent of smelter smoke most injurious to vegetation is sulphur dioxide. This was well established by the work of Wieler in Germany, Haywood and other experimenters in the United States. The speaker, in collaboration with Profs. G. J. Peirce and R. E. Swain, conducted experiments lasting three years on a variety of different plants, using low concentrations of sulphur dioxide, and obtained positive results in every case. The smelting industry in this country was slow to realize the injurious effect of sulphur dioxide. As recently as 1913 the belief was expressed that such injury as had been inflicted was due to other causes, but the great amount of experimental work which has been undertaken by the smelters themselves during the past two years has necessarily altered this belief. In fact the most hopeful aspect of the whole situation lies in the realization on the part of the smelters that the control of their sulphur dioxide output is one of their great problems, and that some means, other than through litigation, must be found for the adjustment of the conflicting interests of the smelting and agricultural industries. The character of this experimental work has undergone great changes. At the outset potted plants in small cabinets were used, then plants in larger pots or boxes in relatively large houses, and finally field conditions have obtained by the use of portable chambers which may be set over plants growing naturally in the open. The latter is doubtless the best method, but requires much space and equipment, and involves an expense which may often be prohibitive.

The effect of sulphur dioxide on vegetation is that of a poison, and its action is quite distinct from that of sulphur trioxide or sul-

phuric acid. The latter destroys the plant tissue, turning it brown or black and giving rise to the appearance usually known as "burn." Sulphur dioxide on the other hand is less immediately destructive. It is absorbed by living plant tissue, combines chemically with some constituent of the plant, remains fixed in the tissue, and, when present in sufficient amount, results in a complete disturbance of the physiological processes normally taking place in the plant cells. Analyses show that the sulphur content of plants which have been exposed to sulphur dioxide is always increased thereby. The visible effects produced vary in character with the conditions which existed at the time the sulphur dioxide came into contact with the plant. In a general way the symptoms may be described as those typical of the effect of any slow poison on a living system. The natural color of the plant fades, portions die slowly and become brown in color, normal growth is inhibited, completely bleached areas may appear, and finally the whole plant may succumb. In the case of trees the leaves or needles fall, the tree then develops another crop, which in turn die and fall, the process repeats itself as often as the tree recovers and the exposure is repeated; later the twigs and small branches lose their life completely, and the last surviving foliage is found along the trunk and main stems in a manner peculiar to this sort of injury. Eventually the tree dies, and is not reproduced by seedlings or saplings. The complete absence of young growth is one of the serious characteristics of "smelter smoke" forest regions. Different species of plants vary widely in their power of resistance to sulphur dioxide, and even among the same species certain individuals show greater resistance than others. The whole effect is therefore gradual and insidious; the destruction wrought is not abrupt and complete.

The details of the chemical reactions taking place between sulphur dioxide and plant tissue are not known. Since a change in color is the first visible result it is possible that chlorophyl enters into the reaction. It is possible that the unsaturated substances which normally combine with carbon dioxide in the process of photosynthesis combine with sulphur dioxide instead, and that the whole process is thus disturbed. The one well-established fact is that the sulphur dioxide is fixed, and the sulphur content of the plant is thus increased. This is true without exception. It has been repeatedly proven by various German investigators, by Haywood in this country, and by the speaker, working first in collabora-

tion with Prof. R. E. Swain, and later independently. I have analyzed approximately 100 samples of various plants which had been exposed to sulphur dioxide experimentally, 600 samples from "smelter smoke" districts, and in every case have found this increase in sulphur content. As ashes record the presence of a fire, as high chloride content records the pollution of a water supply, so high sulphur content records the exposure of plants to sulphur dioxide.

The chemical evidence of smelter smoke injury is of two kinds: that dealing with the deposition of poisonous substances, such as arsenic or lead on the surface of the plants, and that concerning the effect of sulphur dioxide. The first is relatively simple and easily obtainable. The analysis of a sample of hay or grass will disclose the presence of significant amounts of arsenic or lead. A study of the results as regards their distribution in a district, correlated with the records of the prevailing wind directions and the relative amounts at increasing distances from the smelter, will usually give satisfactory evidence as to the source of the poisonous ingredients.

The second class of evidence—that concerning sulphur dioxide—is more difficult to obtain. While it is true that an increase in sulphur content results from exposure to sulphur dioxide, it does not necessarily follow that such increase, when observed in the field, is due to sulphur dioxide. It has been shown that plants absorb sulphur compounds from the soil, and that they do so to an abnormal extent when growing in soils in which large amounts of sulphates are present. It is necessary, therefore, to prove in any given smelter district that the increase in sulphur content of the plant does not come from the soil. This can only be done by analyzing samples of the soil in question and determining their sulphate content. In practice this apparent difficulty is not so serious as it might appear to be. Several hundred determinations have shown that the sulphur content of the soil in a district is very uniform, rarely varying more than two-hundredths of one per cent, and such small variations as do occur are quite independent of the variations in the sulphur content of the corresponding samples of plant tissue. When all the results from a given district are considered, I have never found it possible to discover any relation between the sulphur content of the plants and that of the soil.

The method used for determining whether or not the vegetation

of a district has been exposed to sulphur dioxide depends, therefore, on three steps: first, the determination of the sulphur content of the vegetation in question; second, the comparison of the results obtained with the sulphur content of similar plants growing under similar conditions, except for the possible exposure to sulphur dioxide; and third, the determination of the sulphur content of the soil in which each sample of vegetation grew, in order to eliminate the soil as a source of any abnormally large amount of sulphur found in any of the vegetation. This method was first used on a large scale in this country by Haywood in a study of the forests in a certain smelter district, later by the speaker, in collaboration with Prof. R. E. Swain, and recently by the speaker alone, in a study of the grains in four widely separated smelter districts. The results obtained have been uniformly satisfactory, and have been in complete accordance with the results of botanical studies in the same districts.

The method of collecting samples of vegetation for analysis is of some importance. In case of trees the leaves or needles, in grains the blades, should be taken, and care should be exercised to secure specimens of every age obtainable. Thus on a pine tree all the needles should be taken from one side of a branch, beginning with the youngest growth on the tip, down to the oldest needles remaining on the tree. With grain all the blades on a stalk should be gathered. Furthermore, since the normal sulphur content of different species varies widely, and that of different individuals of the same species varies slightly, a large number of samples of each species under examination should be secured. The same precautions are necessary in the collection of the control samples of normal vegetation, to be used as standards for comparison, and these should be obtained from the same species, growing under similar climatic and physical conditions, and far removed from any possible source of sulphur dioxide.

The methods of analysis which have been used in this work are those commonly employed for sulphur determinations. Thus the vegetation is fused with sodium peroxide and sodium carbonate[1] and the sulphur precipitated, after dehydration and removal of the silica, under the conditions outlined by Folin. The soil samples are extracted with hydrochloric acid and the sulphur precipitated after

[1] Bulletin 107, Bureau of Chem., U. S. Dept. of Agriculture.

thorough dehydration and removal of the silica.[2] These methods require care and attention to many details, but give accurate results. Some examples of duplicate, and entirely independent, analyses are given in Table I, which show the accuracy obtainable.

TABLE I

DUPLICATE DETERMINATIONS SHOWING DEGREE OF ACCURACY OBTAINED

Substance.	Percentage of Sulphur.	
	A	B
Vegetation.....	2.06	2.07
"	0.35	0.32
"	1.66	1.66
"	0.36	0.34
"	0.81	0.80
"	0.58	0.57
"	0.80	0.84
"	0.39	0.39
"	0.35	0.39
Soil.....	0.025	0.022
"	0.025	0.027
"	0.103	0.098

The following Tables II and III give some results obtained in the field, and illustrate the manner in which the method works out in practice. In column three of Table III is given under the heading of "Factor" a number which is simply the number of times the normal amount of sulphur is contained in that found in the sample in question. These tables might be extended to include several hundred analyses, without, however, increasing their value for the purpose of illustration.

The sulphur content of the samples of soil taken from the districts in which the data given in Tables II and III were gathered varies between one- and two-hundredths of one per cent.

If results such as those given above are obtained in a smelter district, and are studied with regard to the relation of the points of collection and the smelter, it will be found that in general the sulphur content of the vegetation increases from all directions towards the smelter. The rate of increase is not uniform from all

[2] Folin, Otto, Sulphate and Sulphur Determinations. Jour. of Biolog., Chem. 1, 137, 1906.

TABLE II

Sulphur Content of Vegetation Not Exposed to Sulphur Dioxide

Substance.	Percentage of Sulphur.	Substance.	Percentage of Sulphur.
Barley	0.38	Wheat	0.27
"	0.36	"	0.28
"	0.30	"	0.38
"	0.42	Average of Wheat	0.31
"	0.41		
"	0.28	Alfalfa	0.43
"	0.36	"	0.33
Average of barley	0.36	"	0.29
		"	0.46
		Average of alfalfa	0.38

TABLE III

Sulphur Content of Vegetation Exposed to Sulphur Dioxide

Substance.	Percentage of Sulphur.	Factor.
Barley	1.27	3.5
"	0.97	2.7
"	1.36	3.8
"	0.85	2.4
"	0.67	1.9
"	0.58	1.6
Wheat	0.62	1.7
"	1.27	3.5
"	1.22	3.4
"	0.82	2.3
"	0.68	1.9
"	0.91	2.5
"	1.01	2.8
Alfalfa	0.99	2.7
"	1.10	3.0
"	1.02	2.8
"	0.87	2.4
"	0.91	2.5
"	0.79	2.2
"	0.84	2.3

directions, but is affected by such general factors as the topography of the district and the directions of the prevailing winds, and such local factors as windbreaks, buildings, and other sheltering agencies. It is very much as if the smelter were surrounded with a great pile of sulphur, highest near the plant and decreasing with increasing distance from the smelter, only in this case the sulphur is invisible to the eye, since it is held in combination within the tissue of the vegetation.

The interpretation of such results as have been presented requires some caution. This chemical evidence is evidence of injury only in the sense that it shows that the vegetation in question has been exposed to sulphur dioxide, which is known to be a substance highly injurious to vegetation. Taken by itself it does not prove that the plants died, or that the crops failed. There is no quantitative relationship known between the increase in the sulphur content and the degree of injury to the plant. The possibility of subsequent recovery by the plants is not eliminated. Taken together with evidence as to the appearance of the vegetation, the time and manner in which the injury was inflicted, the yield of grain or growth of tree, with botanical evidence as to the character of injury and absence of other possible agencies, this method does give evidence, with the definiteness of chemical analyses, that the vegetation in question has been exposed to sulphur dioxide, and that to this exposure may be ascribed the losses which have actually taken place.

DISCUSSION

The CHAIRMAN: Any remarks on this paper?

Mr. DRAKE: I would like to ask, Prof. Mitchell whether he thinks there might possibly be any connection between the amount of absorption and the amount of sulphates present in the soil. If the soil is richer in SO_4 than in SO_2 would the absorption be the same?

Prof. MITCHELL: I don't know anything about that. I haven't found any important variation in the sulphur contained in the soil. If we have variations in the sulphur content of soil they would be shown by the soil analyses.

Mr. DRAKE: You made the statement in your paper that soils containing more sulphates produced vegetation containing more sulphur.

Prof. MITCHELL: That has been proven by other work on the effect of sulphur contained in the soil.

Mr. DRAKE: I merely wondered if a soil higher in sulphates might have a greater tendency to absorption of SO_2 or whether it is reversed?

Prof. MITCHELL: I don't know.

COTTRELL PROCESSES OF ELECTRICAL PRECIPITATION

By WALTER A. SCHMIDT

Read at the San Francisco Meeting, August 28, 1915

The subject which I have been requested to present to-day covers the Condensation of Fumes, Smoke and Dust by Electrical Means, or more specifically the method which is generally referred to as the Cottrell Process of Electrical Precipitation. I reluctantly discuss this subject before your Institute at this time, as there is so little new information which can be presented. The entire question has been fully discussed in numerous articles which have appeared from time to time, following discussions held at meetings of various American Engineering Societies. Recent commercial work with these processes has largely consisted of the development of details of construction and improvements in methods of operation. None of this work lends itself to discussion in a general article, nor would such information be of interest to others than those directly at work in this specialized field. At best, I can, therefore, only hope to re-survey the work of the past eight years, which has resulted in the final development of a new commercial process. In this I find my only excuse for discussing the subject anew.

During the past year or two the progress made by the Cottrell Processes has been so rapid as to place it definitely amongst standard industrial processes. A hurried review of the development work which led to the practical establishment of these processes may, therefore, bring out some matters of interest to the members of the Institute here to-day, as many of you are undoubtedly directly connected with the development of some new process, in which event your experiences in the early work may resemble, in a measure, the ups and downs of electrical precipitation during the past eight years.

In presenting this subject to-day, I will follow rather closely a paper which I delivered to the Canadian Mining Institute during

March of this year. Particular care was taken to make that paper complete up to the date of presentation. As far as I know, that paper has not appeared in print, and it will, therefore, serve well as a basis for to-day's discussion. This present paper will merely bring the former one down to the present date. My continual lack of time must serve as excuse for this short cut to the preparation of a technical article.

The general problem of the removal of suspended matter from gases has been growing in importance for a number of years. On the one hand, this has been occasioned by the increasing seriousness of the pollution of the atmosphere with its subsequent hygienic and economic damage; and, on the other hand, through the ever-increasing demand for greater economy in our industrial processes. This problem has grown steadily with the growth of the factory and the increase in volume of the furnace gases emitted from the exit stacks. In some of our larger industrial centers these furnace gases are of such volume that the ordinary movements of the atmosphere are wholly incapable of effecting satisfactory dilution when the gases contain either poisonous constituents or when they carry large amounts of suspended matter. Then, as the result of keener competition, coupled with the substitution of lean raw materials for the richer ones formerly available, it is becoming more and more important to eliminate losses from all industrial processes. Those losses occasioned through materials being swept along by furnace gases, and out through the exit stacks, compose a large portion of the total losses in many furnace processes. Furthermore, the problem has specific interest through the possibilities offered for improving many industrial processes when gases can be cheaply and effectively cleaned of the suspended particles carried by them.

The removal of suspended particles from gases is a purely mechanical problem, even when the individual particles are exceedingly small, and practically all mechanical forces have been pressed into service in dealing with this question. The different forces have led to the development of as many different processes, each having its particular field of application. I will not discuss any of these processes other than that of Electrical Precipitation, as the principles involved are too well known to the engineer to make a general discussion of value, and the details cannot be presented in the limited space at my disposal. It will serve to-day's purpose

merely to mention, in general, the processes in commercial use at the present time. These may be roughly grouped as follows:

Settling Processes, including settling flues, expansion chambers, wire chambers, baffle houses, etc.; *Filtration Processes,* covering bag-houses, filtration towers, etc.; *Scrubbing Processes,* including all forms of washing towers and mechanical scrubbers, such as the Thiesen, Schwartz-Bayer and Feld washers, as well as the various types of injector scrubbers; *Centrifuging Processes,* embracing ordinary cyclones, complex cyclones, such as the Dyblie Whirler and mechanically revolving whirlers, and lastly *Electrical Precipitation.*

The electrical precipitation processes give us perhaps the only means for taking hold of the individual particles of suspended matter, without being directly encumbered with the treatment of the gases themselves. During the process of treatment, the individual particles are given separate electrical charges, and are then caused to migrate under the electrical forces out of the current of advancing gases. The force which can be exerted upon the individual particle depends upon the construction of the apparatus as well as the electrical characteristics of the gases under treatment. It can readily be seen, however, that a process embodying such selective action between the suspended matter and the gases has a tremendous advantage, when large gas volumes are to be treated, over all processes based upon a mere difference of some specific physical characteristic, as, for example, the difference in inertia as made use of in baffle houses, or the difference in specific gravity as utilized in settling chambers and centrifuging processes. In all such processes the gases, as well as the suspended particles, must be treated, while with the electrical process it is merely necessary to exert a sufficient force upon the individual particle to overcome the buoyancy and carrying power of the moving gases.

The operation of the electrical processes, when analyzed into its simplest factors, may be described as follows:

The gases, along with the suspended material, are passed into an apparatus comprising a system of electrodes. These electrodes are of two types, one type of a form facilitating electric discharge from the surface thereof, the other type of such form as to minimize or prevent discharge from its surface. These electrodes are so placed in the apparatus that the two types oppose each other and a silent or glow discharge is maintained between them by im-

pressing a sufficiently high unidirectional electric potential upon them. The gases are passed through this electric discharge, which may be viewed as a constant stream of ions, or particles of electricity, flowing from the discharge electrode to the non-discharging electrode. As the suspended particles come into this stream of ions they are bombarded by them. Those ions which strike the particles are stopped in their passage from electrode to electrode, attach themselves to the particles and give up their electric charge to them. In this manner the particles gather a sufficient electric charge to move under the force of the electric field between the electrodes, then migrate toward the electrode and are deposited thereon while the gases pass on unaffected. In reality, this principle cannot be so simply carried out, and a great measure of success depends upon the proper design of the apparatus. The composition of the gases, the nature of the suspended particles, the temperature and many other factors must be taken into consideration in designing a plant to handle any specific problem.

You are undoubtedly all familiar with the old laboratory experiment of blowing out a candle by means of the electric windage flowing off of a needle point highly charged with electricity. This windage is caused by the repulsion of the gas molecules from the charged point in a manner similar to the method just described. Gases themselves can be made to move under the electric discharge as the result of the charging of the gas molecules together with the bombardment of these molecules by the constant stream of ions composing the discharge. This action, however, is not nearly so pronounced as the translation of the larger suspended particles, which can be translated with respect to the gases at a remarkable rapidity. If the electrified needle point be given a unidirectional charge—for example, by means of a Wimshurst machine—and an insulated body be brought close to the point, it instantly takes up an electric charge similar in sign to the charge upon the needle point. If such insulated body is free to move, as, for example, a pith ball suspended on a silk thread, it is repelled from the point. If now, such electrified point is placed opposite to a grounded plate and a freely floating particle passed into the discharge between the point and the plate, such particle acts similarly to the pith ball, takes up an electric charge similar in sign to the charge upon the needle point, is repelled therefrom, and upon striking the grounded plate, gives up its electric charge to the plate and is deposited thereon.

This is precisely what takes place in an electrical precipitation apparatus, or so-called treater, the difference being mainly construction details, the choosing of proper electrodes and the substitution of reliable and adequate electrical equipment.

The removal of suspended particles from gases by electric means is fundamentally quite an old idea, it having been independently suggested by a number of investigators at intervals of about twenty-five years for the better part of a century. It seems that the method was first suggested as a means for suppressing smoke by Hohlfeld in 1824. In an article entitled, "The Precipitation of Smoke by means of Electricity," he refers "to the increase of rain and hail after a flash of lightning, and describes how he filled a globe with smoke and led into it a pointed wire connected to an electric machine, which caused the smoke to settle." It was again suggested by Guitard in 1850 in an article in the *Mechanics' Magazine.* Reference is even made to this article in Wiedemann's "Galvanismus." This early work and the suggestions of Hohlfeld and Guitard seem to have been quite forgotten, as nothing ever came of them as far as any records show. During the period roughly designated as twenty-five years following the appearance of Guitard's article, a large amount of work was conducted by Crookes, Thompson, Aitken, Lodge, Tyndall and others upon molecular bombardment. They investigated the repulsion of dust from heated bodies, the force exerted by the bombardment within a Crookes tube and similar phenomena. Oliver Lodge then again brought the subject of electrical precipitation into light in a series of articles appearing in 1884, 1885 and 1886, the main article being published in the Journal Soc. Chem. Ind., 1886, this giving special discussion of the possibilities of electrical deposition of suspended matter from gases. The early work of Hohlfeld and Guitard seem to have remained entirely forgotten until brought to light again in 1905 by Sir Oliver Lodge in an Historical Note published in *Nature* during that year.

The first attempt to apply these forces commercially seems to have been made at the Dee Bank Lead Works and the first patents on the method were granted to Mr. Alfred O. Walker of that firm. He obtained patents in various countries during the years 1884-1886. All of these patents, however, have long since expired. The apparatus was installed in 1885 by the Works Manager, a Mr. Hutchings, with the co-operation of Professor Lodge. It was

described at the time as "consisting of a system of metallic points situated in the flue from the lead furnaces and excited from two Wimshurst machines, each machine driven by a one horse-power steam engine." The apparatus was unsuccessful and nothing further seems to have been done with the process by these early pioneers. Quite independently, Dr. Karl Möller, of Germany, also suggested this method for smoke abatement, and he secured a German patent in 1884. He, however, did not develop any commercial application, but his son, Erwin Möller, has done considerable development work on the processes, and is now actively engaged, together with our American interests in the prosecution of the work upon the continent of Europe. In 1900, Eissler again called attention to the work of Walker, and since then an occasional publication has kept the process in the public eye.

Our work commenced in 1906 when Dr. F. G. Cottrell investigated various problems in connection with the Contact Process of sulphuric acid manufacture. Dr. Cottrell was at that time Professor at the University of California. He is now Chief Chemist of the U. S. Bureau of Mines,* and is no longer interested commercially in the processes which bear his name. In 1906 Cottrell was confronted with the problem of removing sulphuric acid mist from gases before these went to the contact towers. He repeated the early experiments of Lodge and became convinced of the possibilities in the method. The first large scale tests were made at the Hercules Works of the E. I. du Pont de Nemours Powder Company at Pinole, on San Francisco Bay, where the gases from a Mannheim Contact Sulphuric Acid unit were employed. These tests, although by no means complete, demonstrated conclusively the commercial possibilities of the process. Since then the work has largely been the development and reduction to sound engineering practice of the fundamental principles disclosed in this early work. The failure of the early commercial work of Lodge and Walker can without doubt be largely attributed to the unsatisfactory and unreliable electrical equipment then available. Modern electrical apparatus has made the development of these processes a much easier task than that which confronted the early pioneer investigators.

For a full bibliography of the early work, I will refer you to an article by Cottrell, entitled "Problems in Smoke, Fume and

*At present Dr. Cottrell is Chief Metallurgist of the Bureau of Mines.

Dust Abatement," published in the Report of the Smithsonian Institution of Washington for the year 1913 to 1914, which, however, did not appear in print until February of the present year.

The commercial development of these processes since Cottrell's first experiments can best be described by means of lantern slides. I will show a series of views at the close of this paper, illustrating the development of the present type of apparatus and electrical equipment, and showing some of the more interesting construction details. A few views will illustrate the operation of the processes, as well as this can be shown by means of lantern slides. Those of you who are interested in seeing the principles of the processes illustrated by experiment will find a working model at the Panama-Pacific Exposition in the Metallurgical Exhibit of the U. S. Bureau of Mines. At that Exhibit you will also find a model of the treater installation at Trail, British Columbia, and a display of representative materials collected in practice. I will merely indicate here the progress which has been made commercially, and point out some of the fields of application in different industries where the processes have been shown to be of value.

The first commercial application of our processes was made at the works of the Selby Smelting and Lead Company on San Francisco Bay. This company was threatened with injunction suits on grounds of the alleged damage done by the sulphuric acid fumes escaping from the kettles of boiling sulphuric acid in which the silver was parted from the gold in the alloy coming from the cupels. The striking results obtained in the experiments at Pinole in the precipitation of sulphuric acid mist, drew the attention of the Selby Company and, after a few successful preliminary tests, a treater was constructed in 1907. This treater has been in constant service ever since and several duplicate treaters have been constructed elsewhere. This apparatus treats approximately four thousand cubic feet of gas per minute. The apparatus is constructed in a flue having a four by four foot cross-section. The collecting electrodes are lead plates four feet long and four inches wide, spaced five inches apart. The discharge electrodes consist of serrated micanite clamped between strips of hard lead. The electric power is taken from the 460-volt, 60-cycle factory power line, transformed up to 17,000 volts and rectified by means of a synchronous contact maker, the resultant intermittent direct current energizing the discharge electrodes. The power consumption of the complete apparatus,

including the driving of the rectifier, is two kilowatts. No additional men are employed to operate the apparatus and full operating costs, including power, repairs and attendance is approximately twenty dollars per month. The acid collected is of 40° B. strength, and when the kettles are boiling vigorously over two gallons per minute of such acid is collected. As far as any records show, this was the first commercially successful electrical precipitation apparatus ever constructed.

Following upon this work a series of tests were made upon the roaster gases at the same works. An experimental treater was constructed which handled the full quantity of gas passing in the flue, amounting to fifty thousand cubic feet per minute. The general design of this treater was similar to that of the Parting Flue Apparatus just described. Fundamental changes in metallurgical practice at the smelter made the installation of the permanent equipment unnecessary.

The next installation was at the Balaklala Smelter at Coram, in Shasta County, California. This smelter was in the heart of the Shasta Copper Belt, together with the Keswick Smelter, the Bully Hill Smelter, and the Smelter of the Mammoth Copper Mining Company. As the result of litigation, certain restrictions were placed upon all of the smelters in this district, relative to fume control. These restrictions included the removal of all suspended matter from the exit gases and the dilution of such gases to prevent the sulphur dioxide content from exceeding three-quarters of 1 per cent. The Bully Hill and Keswick Smelters suspended operations, the Mammoth Smelter installed a bag-house and the Balaklala undertook the installation of the Cottrell Processes. This was the first large installation of these processes, and it was necessary in the design of this apparatus to figure far beyond the experimental and test data then available. The gas volume was approximately 250,000 cubic feet per minute. The general design of treater was similar to that installed at Selby, except that iron was used instead of lead, the gases being non-corrosive. Nine units of ten by ten foot cross-section were built in parallel, each connected to a common inlet and outlet flue. The entire structure other than the flues was built of iron. The collecting electrodes were of No. 10 sheet iron, ten feet long and six inches wide, spaced five inches apart. The discharge electrodes were made of asbestos fiber interwined between iron wires. Serrated micanite

twisted between iron wires was also used. This apparatus was operated on about twenty-five thousand volts. The collected fume was dry and adhered to the electrodes. To remove this collected material from the electrodes, one unit at a time was by-passed and the electrodes given a mechanical jarring or rapping, the dust falling into hoppers from which it was removed by means of screw conveyors. Each unit was cleaned once in eight hours. During the cleaning of one unit the remaining eight treated the entire volume of the gases. The total cost of the installation, including flues, fans, motors, and electrical equipment, was one hundred and ten thousand dollars. The power consumption was about 120 kilowatts. The attendance was one man per shift to attend the electrical generating apparatus and two men and a foreman per shift to look after the cleaning of treaters and the removal of the precipitated fume. The amount of material collected was eight tons per twenty-four hours, this being a very fine dust high in copper and zinc, but was not of particular commercial value, due to its high zinc content. The entire smelter was closed down in July, 1911, as the result of litigation troubles, it being decided to discontinue operations until such time as a practical method could be developed for removing sulphur dioxide as well as the suspended particles from the gases.

Shortly before the work at Coram was discontinued, experiments were commenced at the plant of the Riverside Portland Cement Company on the problem of removing from the furnace gases the dust carried out of the rotary kilns used for the burning of cement. This problem was quite different from those upon which the processes had been tried up to that time. This difference was occasioned by the dryness of the gases, as well as their high temperature. The enormous volume of gases and the large quantity of dust which had to be handled also presented new problems. The Riverside Portland Cement Company, with its factory in the heart of the fertile orange belt of Southern California, had become the center of serious agitation which threatened the factory with an ultimate injunction. Many demands had been met by damage payments and much land was purchased from complaining neighbors, but although the company was exceptionally liberal in meeting the demands of the growers, it became apparent that the dust had to be prevented from escaping into the atmosphere or run the risk of having the operation of the factory discontinued by injunction.

The experimental work at this factory included the building of several fair-sized treaters, roughly seventy-five thousand dollars having been expended upon the preliminary tests. These, however, proved successful. The final installation was put into operation

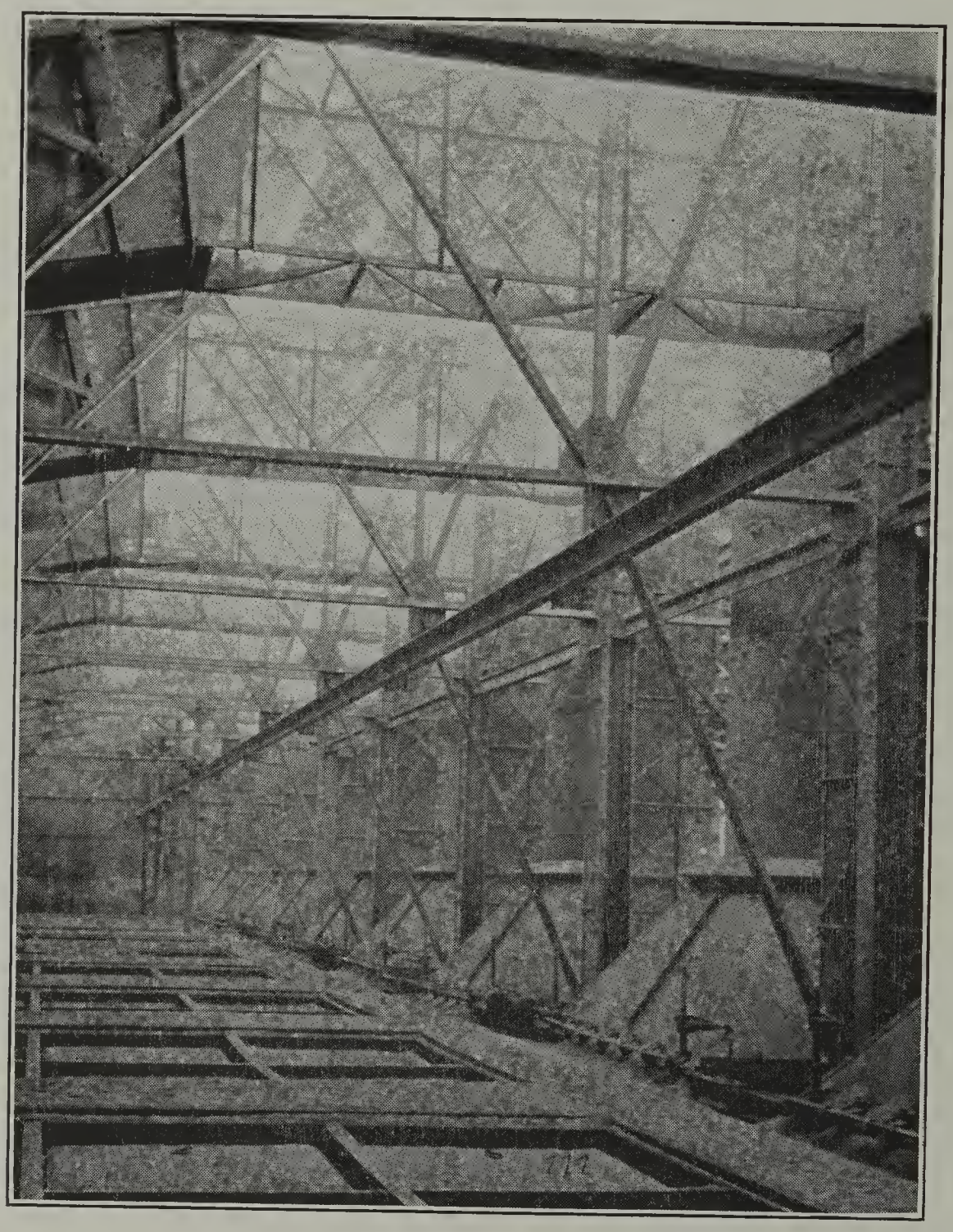


FIG. 1.—View across south half main installation Riverside Portland Cement Co., Riverside, California.

in January, 1913, and has been in continuous operation ever since. This installation treats nearly one million cubic feet of gas per minute, the temperature being four hundred and fifty degrees centigrade. The amount of dust collected averages about ninety

tons per twenty-four hours. The gas volume, as well as the quantity of dust, vary greatly, depending upon the operation of the

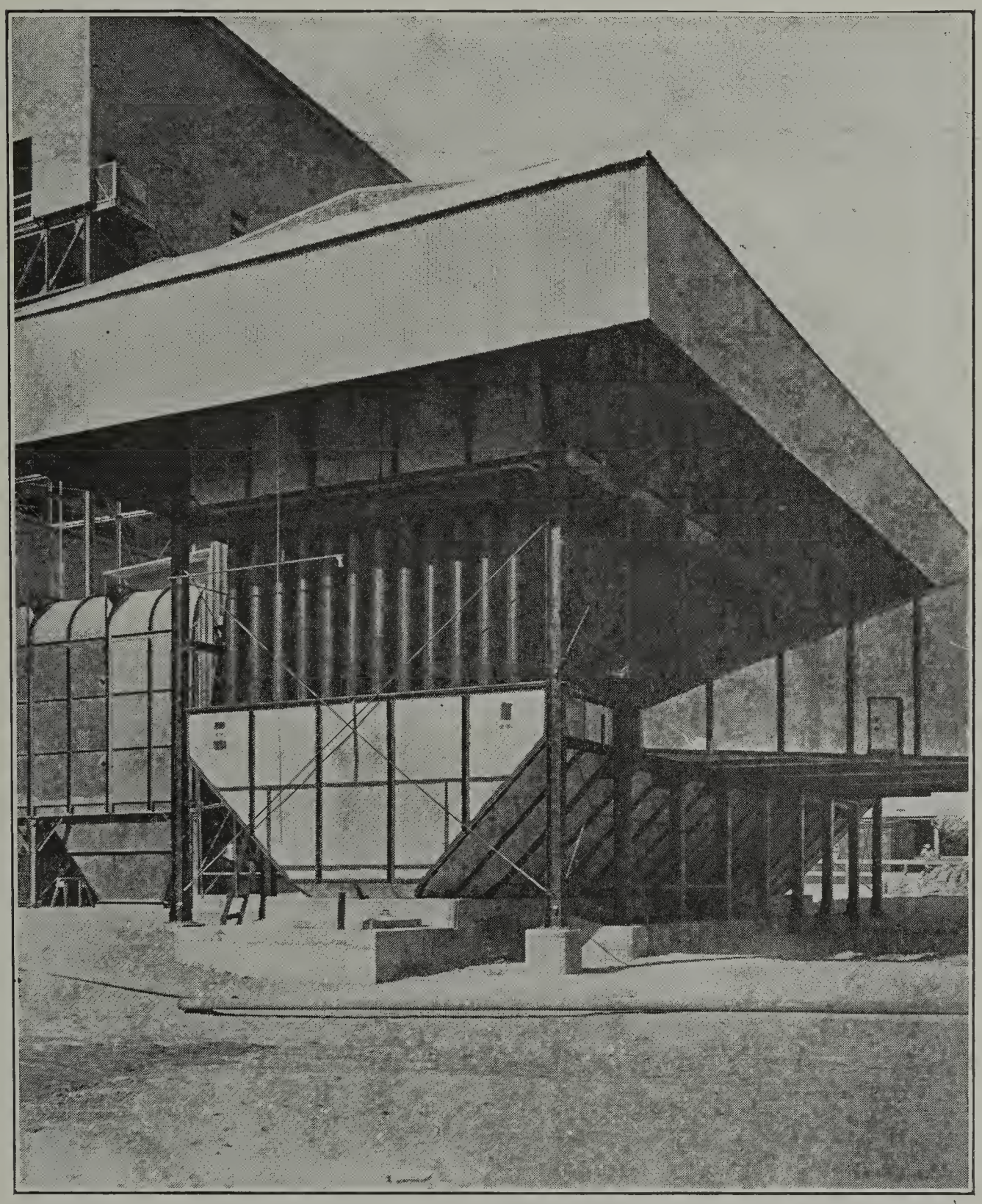


FIG. 2.—Vertical type of Treater installed at Riverside Portland Cement Co., Riverside, Cal. This is the equipment in which the high concentrated potash material is collected as described in body of paper.

furnaces. The total power consumption of this installation, including the motors driving the rectifiers and the screw conveyors removing the collected dust, is forty kilowatts. The efficiency of

collection of the suspended particles average better than 95 per cent, the escaping material being largely potassium and sodium sulphate. The heavy dust is all collected in the treater. The attendance has consisted of one operator and a helper per

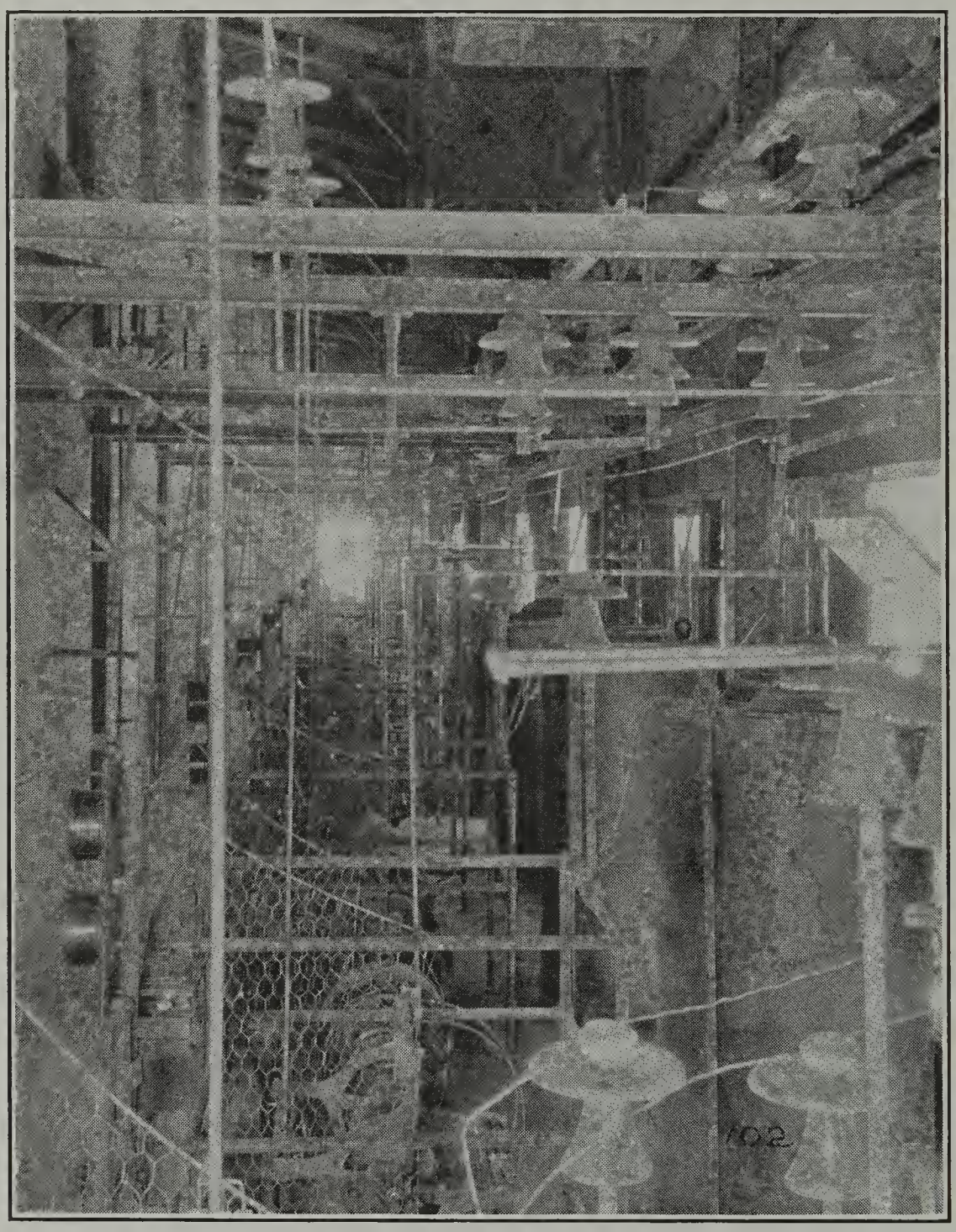


FIG. 3.—View down Electrical Control Room Riverside Portland Cement Co., Riverside, Cal.

twelve-hour shift, but this has recently been changed to one man per eight-hour shift. The cost of this installation was high as there was no space available for the construction of the apparatus within the factory, and the entire construction had to be carried over the building and placed upon a platform eighty feet above the ground.

Each of the ten furnaces was maintained independent of the others, and each was equipped with two treater units, each treater suf-

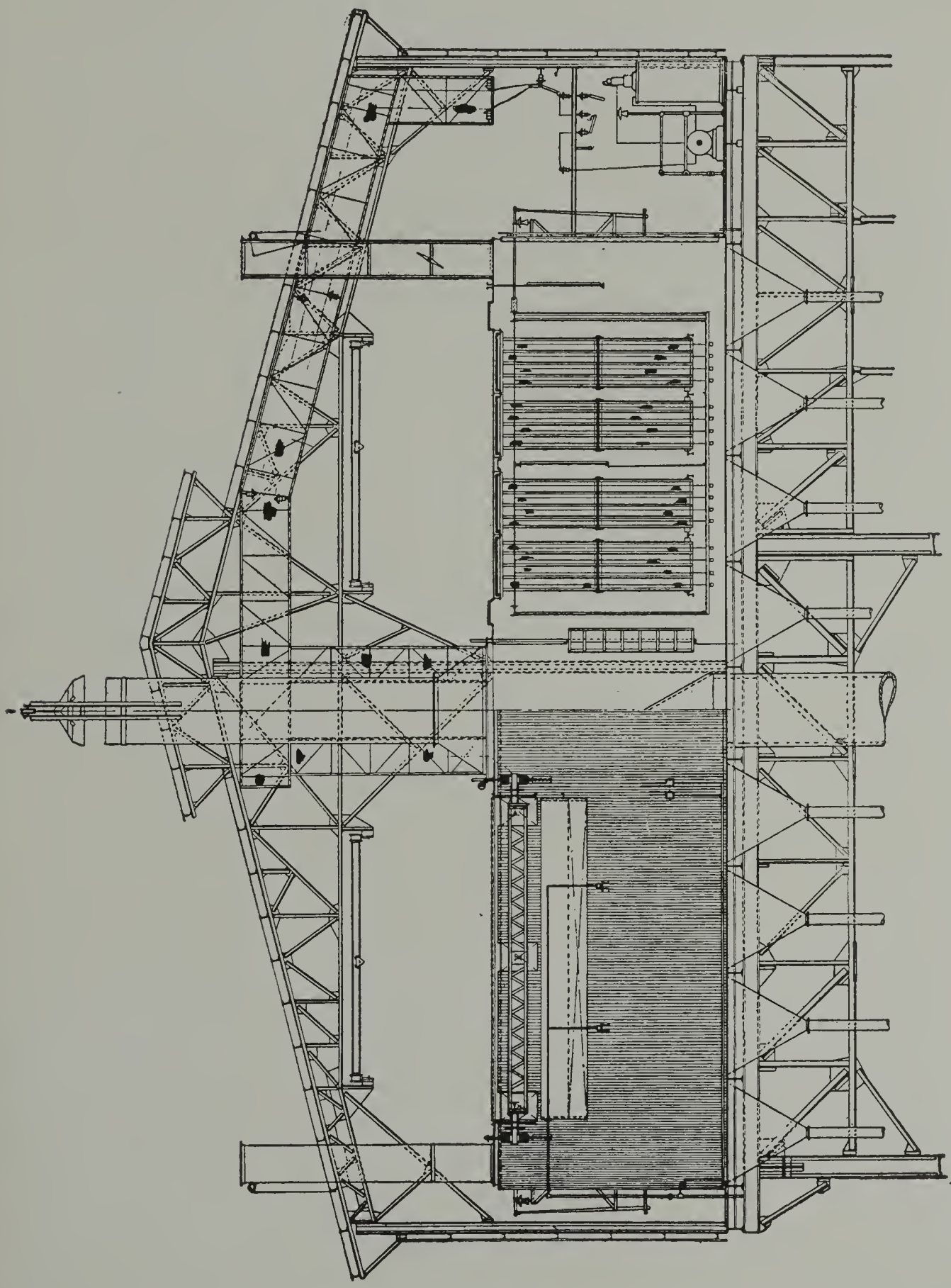


FIG. 4.—Cross section through Main Installation, Riverside Portland Cement Co. This sketch shows general features of Horizontal Type of Construction.

ficiently large to handle the entire gas volume coming from the corresponding furnace. This was done to insure absolute certainty of operation, should difficulty arise with any one unit. The furnaces

were kept independent of one another to give greater freedom of operation, independent stacks being the universal rule in cement factories in this country. The entire structure, including electrical equipment, cost $165,000, of which over half went into the expensive platform sub-structure and housing.

The details of design of this installation are considerably different from the Selby and Balaklala treaters. Slides will be shown illustrating the more interesting construction features of this, as well as other installations. The collecting electrodes are made of wire mesh reinforced with iron angles and are spaced twelve inches apart. The discharge electrodes are iron wire. The operating potential is 45,000 volts. The removal of dust from the electrodes is effected by a simple mechanical system, the electrodes being jarred by means of air hammers and the dampers operated by means of air cylinders, all controlled from the operating platform. The dust falls into hoppers and runs to screw conveyors, which feed into automatic scales, and from there it is dumped into a general cross conveyor, which carries the dust to the bins. The treaters are cleaned once every hour, the cleaning of the entire twenty units requiring less than five minutes.

Recently an additional kiln was installed at this factory, in which all of the collected dust is now burned to cement. Formerly the dust was disposed of as a soil dressing. The dust is partially calcined raw mix, containing no cement, but carries about 2 per cent of potash. This material makes a splendid dressing for certain soils. With the present practice of making cement out of the dust, the potash is concentrated, and the dust caught from the new kiln has a potash content varying from 12 to 21 per cent K_2O, depending on whether the kiln burns all dust or part dust and part raw mix. The general treating system does not supply sufficient material to permit operating this kiln exclusively upon dust.

There is one interesting feature in connection with this installation. Although the main equipment was installed to guard off injunction proceedings and the new kiln was installed largely to dispose of the collected material, as the location of the plant made it inconvenient to dispose of the dust for soil-dressing purposes, still the final result was the first potash recovery plant ever put into commercial operation, and in which soluble potash salts were obtained directly from feldspathic rock. The raw mix at this plant is composed of limestone and a decomposed granite high in feldspathic

material. This decomposed granite varies greatly in composition in different parts of the quarry, but contains about seventy-five hundredths of 1 per cent K_2O on the average. The granite forms one-quarter of the raw mix, giving a K_2O content in the raw mix of less than one-fifth of 1 per cent. The potash content in the dust from the main treating system averages 2 per cent, while the final product exceeds 20 per cent K_2O when dust is burned ex-

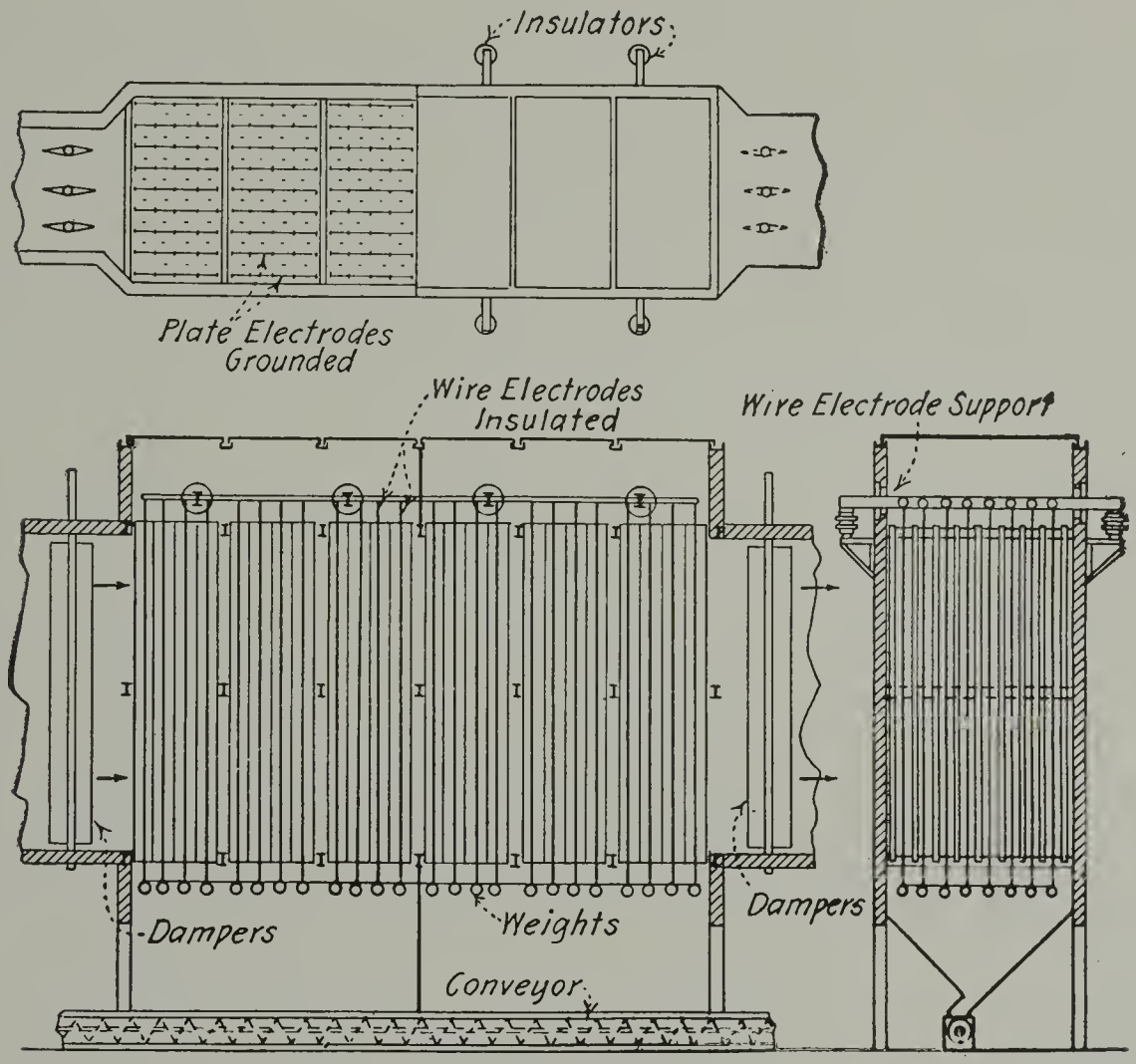


FIG. 5.—Schematic drawing, Horizontal Type of Treater Construction.

clusively in the concentrating kiln. Four to five tons of this concentrated material is caught per twenty-four hours. This material is used as a soil dressing in the groves and on the farms owned by the Cement Company, and the balance is disposed of at a good profit to the Company. Although these results may not be striking from the viewpoint of independent potash manufacture, they serve to demonstrate beyond question the possibilities in the recovery of potash from feldspar, particularly if this can be carried on as a by-product process to cement manufacture. Vast deposits of feld-

spar are available, averaging as high as 10 per cent K_2O, while the Riverside material only runs three-quarters of 1 per cent.

Until the completion of the Riverside installation, little attempt was made to advance the commercial progress of the processes, it being considered sounder policy to work out construction details in a few installations close to headquarters. During the

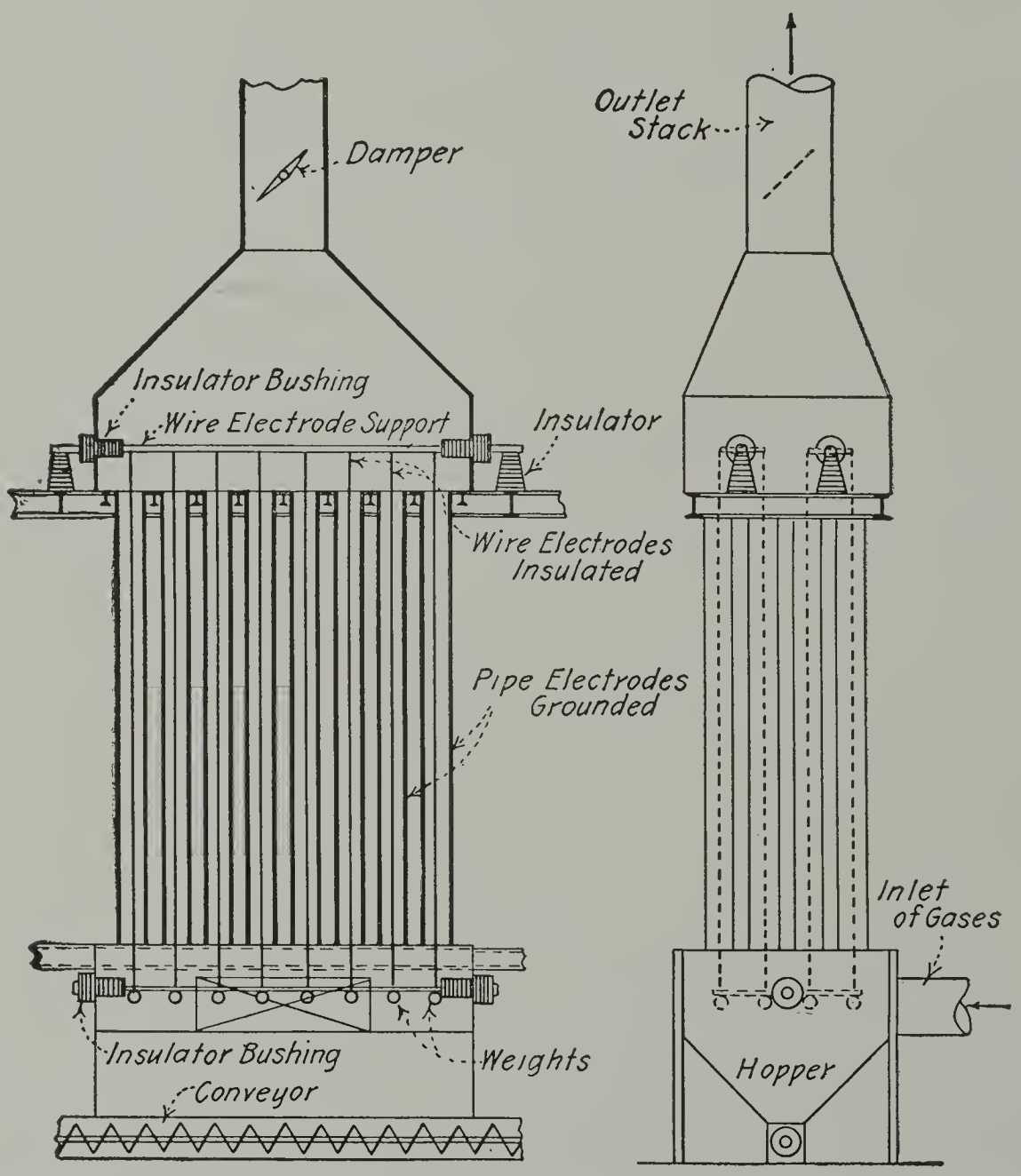


FIG. 6.—Schematic drawing—Vertical Type of Treater Construction.

early part of 1912, Dr. Cottrell became the moving spirit in the formation of the Research Corporation, which is, in a measure, a subsidiary of the Smithsonian Institution and he liberally donated to it all rights to his processes in the United States east of the Rocky Mountains, excepting the application to the cement industry. The latter rights and the rights in the Western Territory of the United States had previously been acquired by the interests

now composing the Western Precipitation Company. This latter Company also holds the rights to the processes in Canada and Mexico.

After the completion of the Riverside installation and the formamation of the Research Corporation, general prosecution of the commercial development of the processes was undertaken. Since then progress has been rapid and the scope of the work has been

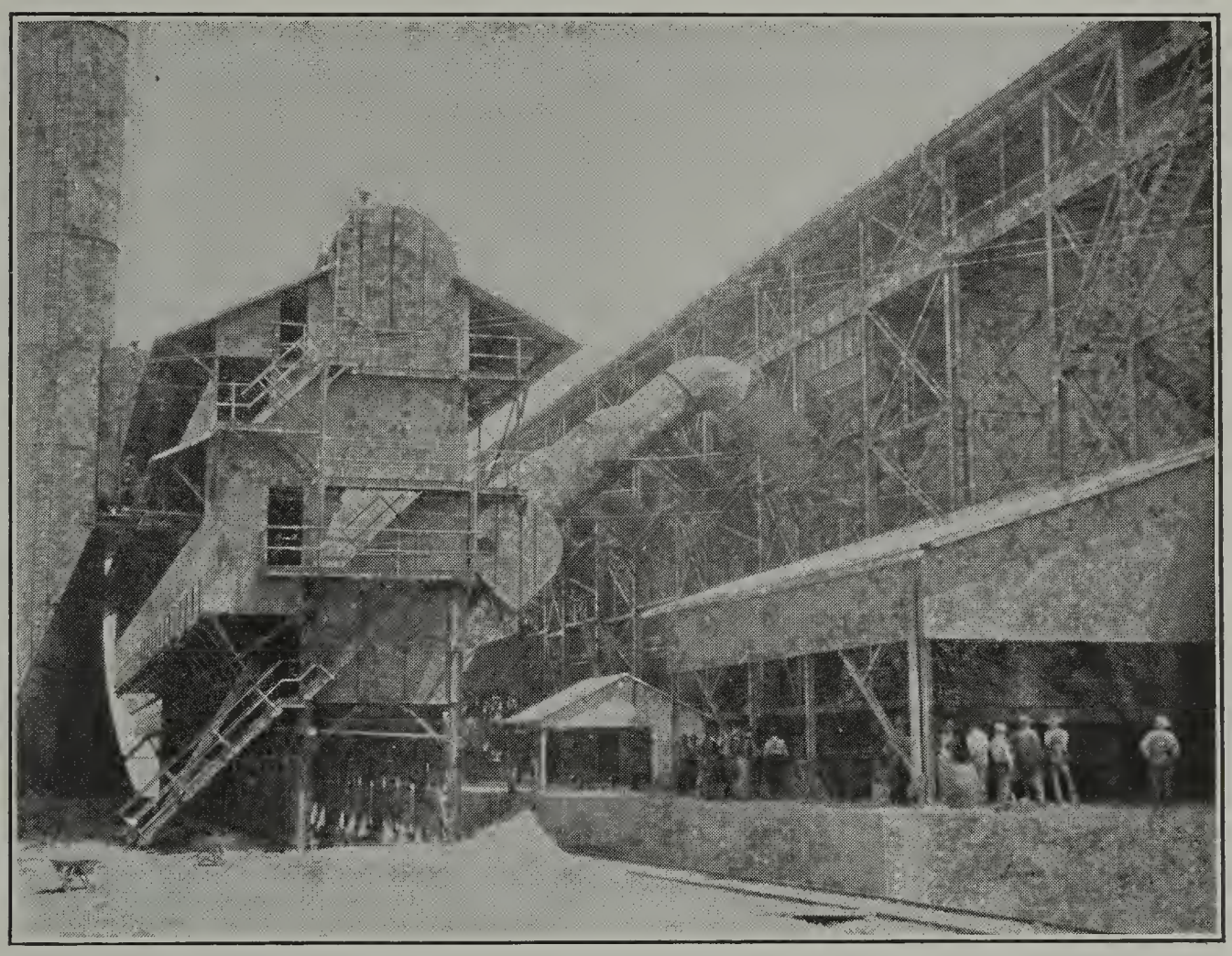


FIG. 7.—Converter Installation. Inspiration Smelter, Inspiration, Ariz. Vertical type of construction.

broadened immensely. The following are some of the more important applications of the processes.

At the Garfield Smelter near Salt Lake City the gases from the copper converters are treated in a precipitater of a different type from those just described. The collecting electrodes are cylinders five inches in diameter, the discharge electrode being suspended along the axis of the cylinder. We differentiate between this type and the Selby type of treater by terming one "multiple pipe treater" and the other "plate treater." The Garfield tests were

commenced in 1911 and the final installation was put into operation in 1914. The final installation consists of seven sections each having its separate electrical energizing set. Each section is composed of 360 five-inch iron pipes, ten feet long, a total of 2520 pipes in all. The total volume of converter gas is being treated in this installation, being approximately 200,000 cubic feet per minute. In contrast with the Selby, Balaklala and Riverside treaters, the

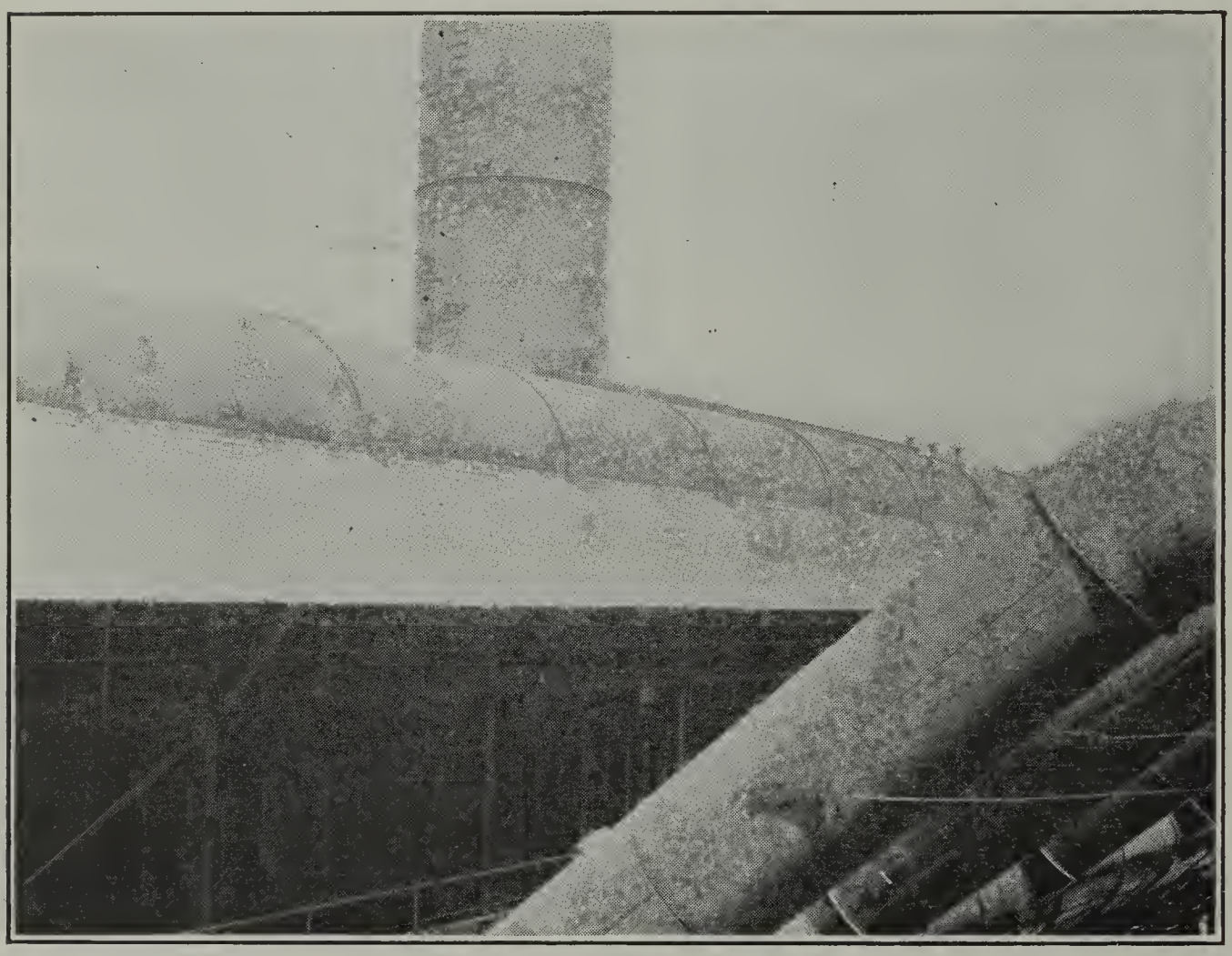


FIG. 8.—Near view of installation showing Fig. 7. Showing Gas Headers, as well as tubes constituting Electrical Treater.

Garfield installation was built entirely to effect a saving of the copper and lead losses from the converters. The efficiency of collection of the suspended matter averages about 90 per cent. The installation, including the electrical equipment, but exclusive of the flue connections, cost approximately fifty thousand dollars. The power consumption is roughly fifty kilowatts and one operator and a helper are employed per shift.

The recent installation at the plant of the Riverside Portland Cement Company, above mentioned, is also of the multiple pipe type.

This treater consists of 480 pipes, each twelve inches in diameter and ten feet long. The kiln draft is supplied by a fan exhauster installed at the exit of the treater. The operating potential of the apparatus is 45,000 volts, and one of the former reserve electrical sets is being used for energizing this new treater unit. No additional men are employed on this treater, as the crew operating the old installation can readily take care of all of the additional work demanded by this new unit. The power consumption is about five kilowatts.

The largest installation for metallurgical use has recently been placed in operation near Globe, Arizona, at the new Inspiration Smelter of the International Smelting and Refining Company.* Two complete treater installations are installed at this plant. The largest of the two treats the gases from the copper converters. The total gas volume which this treater will handle is estimated at about 300,000 cubic feet per minute. At present the full output of the smelter has not been reached, as the new Inspiration Mill is not completed and only one converter has been operated at any one time up to the present date. The second installation handles the gases from the dryers. The latter is a new problem of special interest. At the Inspiration and the Miami mills the table middlings are being treated by the flotation process to recover the finely divided sulphides. At the Inspiration plants, the flotation concentrates are filtered in Oliver filters, and dried in Wedge furnaces, then sent to reverberatories. The Wedge furnaces are equipped with twelve electrical treaters, placed almost directly over the furnaces, and each treater discharges through a separate short stack into the atmosphere. The treaters, therefore, are virtually a part of the stack. Each of these twelve treaters consists of twenty twelve-inch pipes, fifteen feet long, and the discharge electrodes are of iron wire. These treaters were installed for the purpose of saving the fine particles of dust which are carried out of the dryers by the draft. A considerable quantity of dust is being carried from these dryers, due to the extreme fineness of the flotation concentrates. The dryer plant has operated from the beginning with practically complete clearance of all suspended particles. The converter installation, like the dryer plant, is of the multiple pipe type, the pipes being twelve inches in diameter and fifteen feet long.

*Since the presentation of this paper the name of this company has been changed to International Smelting Co.

This installation comprises twelve sections of sixty-four pipes each, or a total of 768 pipes,

The final data upon the converter and dryer installations at the Inspiration smelter is as follows:

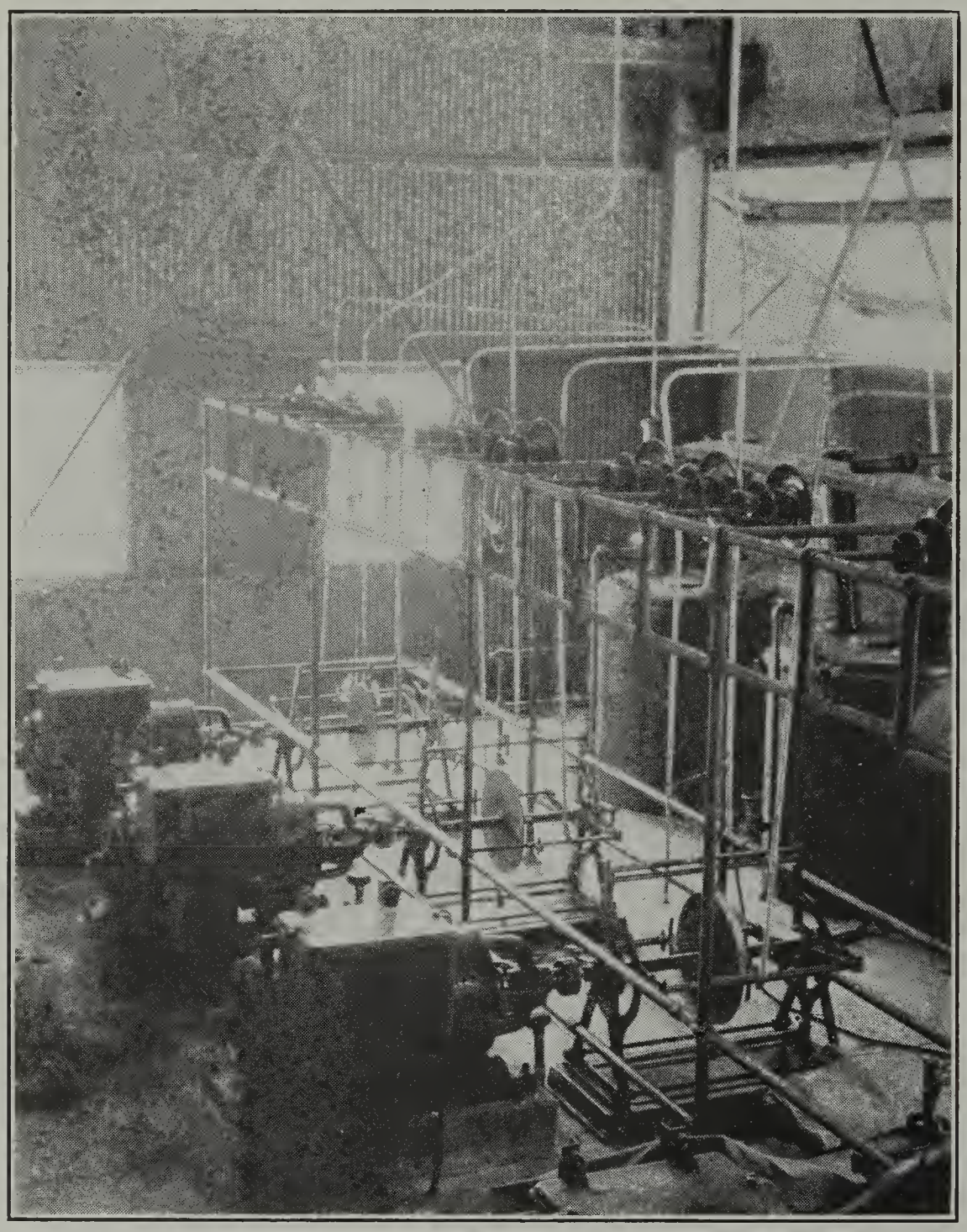


FIG. 9.—Corner of Electrical Control Station—Inspiration Smelter.

Converter Plant: Gas volume 265,000 to 300,000 cubic feet of gas per minute—gases rise from five copper converters.

The temperature at which the gases are treated is such as to allow most of the sulphuric acid to pass through the treater unaffected while the suspended copper is precipitated. During the

final tests the total loss of copper issuing with the stack gases amounted to 54 lbs. per 24 hours. The amount of copper in the escaping fume is 1.8%.

Treater efficiency 98.2% figured on the copper.

Dryer Plant: Gas volume 25,000 to 30,000 cubic feet per minute. Efficiency practically 100%—no visible material escaping from the exit stacks. 8 tons to 14 tons per 24 hours, of material collected.

Another multiple pipe treater is in operation at Trail, B. C., at the smelter of the Consolidated Mining and Smelting Company, of Canada, Limited, this treater having been installed for the purpose of saving the lead losses from the lead blast furnaces. This treater consists of 384 twelve and one-half inch, inside diameter, pipes, fifteen feet long. The installation is divided into twelve sections of thirty-two pipes each, all operating at present on one electrical energizing set. This treater is somewhat overloaded at present, and an additional six sections are now being installed. Approximately one hundred thousand cubic feet of gas per minute is being treated in this installation, at a temperature varying from two hundred to three hundred degrees Fahrenheit. The gases come from three new lead blast furnaces recently installed at this smelter. The dust collected at present in the treater, exclusive of that collected in the collecting flues, averages about six tons per day. The collected dust averages 65 per cent lead and carries a small amount of silver. The lead is present as oxide, sulphide and sulphate, in varying proportions depending upon furnace conditions. This fine dust readily sinters, it being sufficient to place the dust in brick-lined cylinders having a perforated bottom and open at the top. Sintering is started by local heating with a few sticks of wood, and air is then blown through the mass. The sintered material is sent to the blast furnaces. The Trail installation consumes about fifteen kilowatts of electrical energy, and one operator per shift is sufficient for complete attendance. This treater differs from other newer treaters in that no mechanical cleaning system has been installed, the management considering that the operator would have insufficient work if the task of rapping the pipes were eliminated. The cost of this installation cannot readily be ascertained, as it composed a part of extensive reconstruction work affecting the entire blast furnace department. It is estimated that the installation complete, exclusive of flue connections, cost between

thirty and thirty-five thousand dollars. The operating potential of this treater is seventy-five thousand volts.

FIG. 10.—Model Electrical Precipitator shown at Panama Pacific International Exposition, Bureau of Mines Exhibit. This model shows in miniature one-third of the installation at the Consolidated Mining & Smelting Co., Trail, B. C. The Trail Treater collects lead fumes from lead blast furnaces. This installation is of Vertical Type of Construction.

A second treater has recently been completed at Trail, this treating the combined gases from two Wedge furnaces, one Dwight

Lloyd Sintering machine and thirty-six Huntington Heberlein pots. Another treater is under construction at this plant to handle the converter gases. It is also planned to install an electrical treater at the refinery at Trail to collect the fumes from the Dore furnace and the melting pot. This latter fume carries considerable silver, some gold and about 55 per cent antimony. The metallurgical problem will be to separate the arsenic from the antimony after the fume is collected.

A problem similar to that of the Trail Refinery has been met by a treater installation at the Refinery of the Raritan Copper Works at Perth Amboy, New Jersey. This installation is of particular interest in that the treater was installed beyond the water scrubbers, which were formerly assumed to give satisfactory cleaning of the gases. The values collected, however, are sufficient to form a large item of saving, particularly as the operating costs are very low. The electrical energy consumed is less than 3 kilowatts and no special attendants are required.†

Numerous other installations have been made at metallurgical and chemical works for permanent use and some for experimental purposes. As the time is short, we will pass over these, as a description of them would largely be a repetition of that which has just been mentioned in describing the foregoing installations. It is sufficient to state that each particular installation requires a re-arrangement of parts to meet structural requirements, or a re-adjustment of electrode systems, change in construction details and modification of electrical equipment to meet specific conditions determined by gas composition, fume composition and temperature. It may be of interest, however, merely to mention some of these installations to show the broad variety of problems which these processes have been called upon to solve.

At the Omaha Refinery of the American Smelting and Refining Company, a treater has been installed for the collection of sulphuric acid mist, this being similar to the first treater installed at the Selby Works. A similar installation is to be made at the Baltimore Refinery.

† This installation has been fully described by Mr. C. A. Aldrich of the Raritan Copper Co., in an article entitled "Treatment of Silver Furnace Fume by the Cottrell Process," presented at the 28th general meeting of the American Electrochemical Society at San Francisco in joint session with the Am. Inst. of Elec. Eng., Sept. 17, 1915.

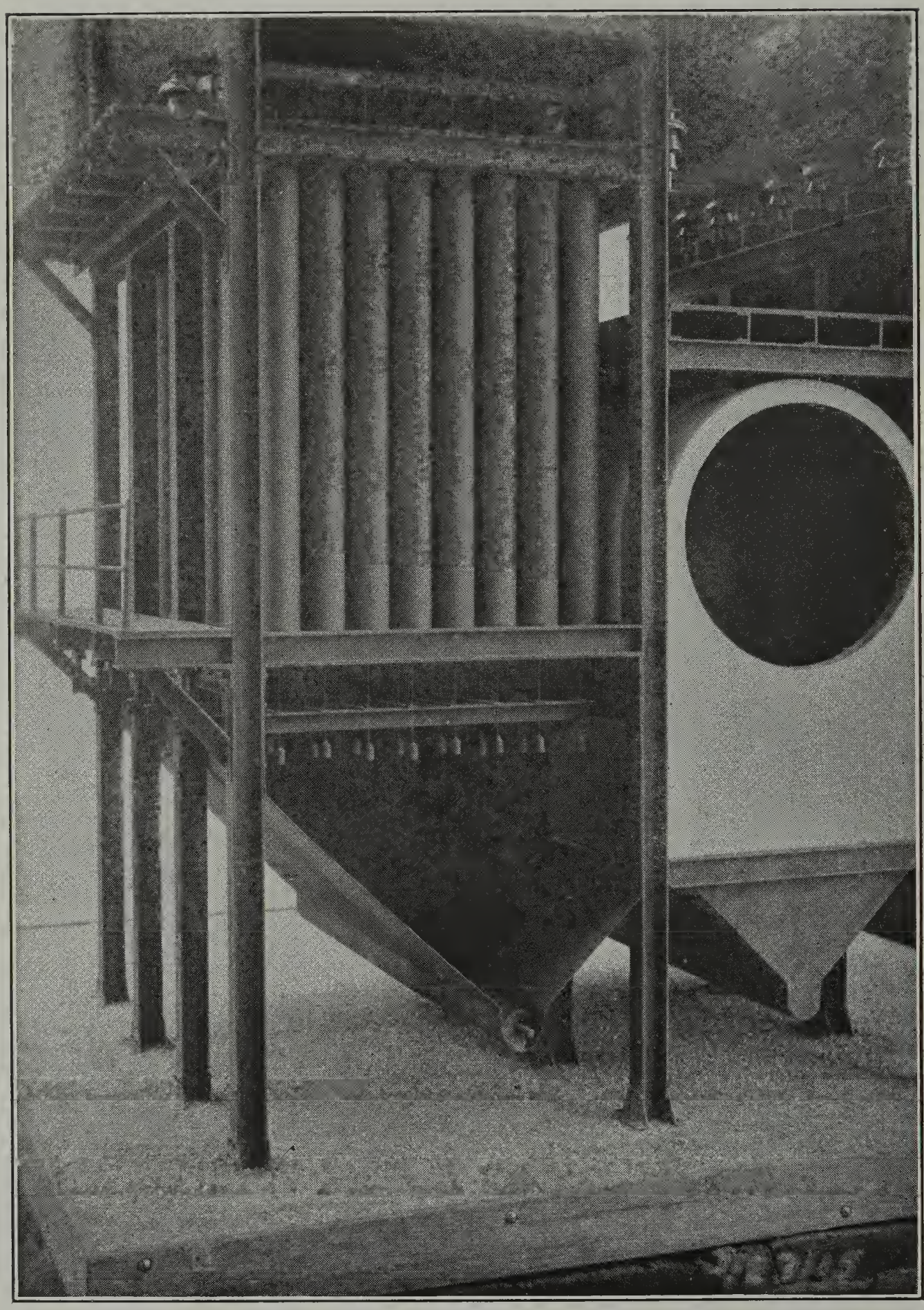


FIG. 11.—Close view of model shown in Fig. 10.

At Tooele, Utah, a treater has been installed to treat the gases from two Dwight Lloyd Sintering Machines, a total of twenty thousand cubic feet of gas per minute. The collected fume is mostly lead oxide, but carries considerable elemental sulphur. This installation is to be enlarged to embrace the remaining eight sintering machines.

At the Goldschmidt Detinning Works near Chicago, the processes are collecting tin oxide; at the Vulcan Detinning Works near New York experiments were made showing the feasibility of collecting hydrated tin chloride. At the Kings County Foundry, a mixture of tin oxide with lead and zinc oxide was collected, this fume resulting from the furnacing of old tin scrap in a cupola furnace in smelting this for the manufacture of sash weights.

A plant is being installed at the Tacoma Smelter of the American Smelting and Refining Company to treat all of the gases arising in the smelter, the combined gases from all of the furnaces now passing to a single stack through a common flue. The gas volume will be between four hundred thousand and five hundred thousand cubic feet per minute.

Dust is being removed from hot Wedge furnace gases prior to their entrance into the Glover Tower at the sulphuric acid works of the Chemische Fabrik Griesheim, near Frankfurt, Germany. In this installation the removal of dust is practically complete and the quality of acid produced has been considerably improved and the troubles in manufacture caused by the choking of the Glover towers have been entirely eliminated. This installation treats three thousand cubic feet of gas per minute at a temperature of 450 degrees centigrade. It consumes less than one kilowatt of electrical energy, and requires no special attendance. About four hundred pounds of dust are caught per twenty-four hours, this being mostly iron oxide, containing a small amount of arsenic. Four similar installations have recently been constructed at the Chemische Fabrik Bochum near Hannover, and one at the Elberfelde Farbenfabrik near Cologne. Tests on a similar problem were also conducted at the Works of the Grasselli Chemical Company at Cleveland, Ohio, and a treater is now under construction at that plant.

Sulphuric acid mist will be removed from roaster gases before these are discharged into the atmosphere, in a treater now under construction at the smelter at Sulitjelma, Norway. Similar work is contemplated in Arizona where this problem is of special economic

value. If the large quantities of acid now escaping with the roaster gases can be collected cheaply, it can then be used for leaching the low grade oxidized copper ores so abundant in that section of the country.

A treater is now being installed at the copper works at Duisburg, near Düsseldorf, for cleaning the combustible gases coming from the iron blast furnaces, prior to burning these gases under the boilers. Tests on a similar problem are contemplated at the works of the Bethlehem Steel Company at Bethlehem, Pennsylvania.

We are at present conducting an extensive series of tests at the Gas Works in Vancouver, B. C., in which one step is the detarring of illuminating gas by means of the electrical processes. This has been entirely successful. Similar work has been conducted at the Ann Arbor Gas Works.

Carbon and lamp black have been collected from the boiler gases at the experimental boiler plant of the Bureau of Mines at Pittsburgh, and from the generator gases at the Gas Works at Santa Rosa, California. The main difficulty in connection with this problem is to remove the collected fluffy carbon from the electrodes. As this is not a simple problem, we have devoted most of our efforts to other fields.

Naphthalene and other heavy hydrocarbons are being collected at the Gas Works at Portland, Oregon, in the briquetting plant, where the lampblack from the petroleum gas generators is dried and then pressed into briquettes for fuel purposes.

Tests were made at Nipissing, Ontario, for collecting mercury fumes arising during the refining of the amalgam sponge. The process collected this fume effectively.

A treater has been installed at the plant of the Universal Portland Cement Company near Chicago, a problem similar to that of the Riverside plant. This treater was installed for test purposes, but handled all of the gases from one large kiln, approximately one hundred thousand cubic feet per minute, operating under excessive temperature strains.

Dried milk, dried eggs and similar substances, manufactured by the spray drying process, have been successfully collected and a treater has been installed for the Milk Flour Company at Chicago.

Sugar dust has been collected in a test treater at the factory of the California Hawaiian Sugar Refining Company at Crockett, California.

Hydrochloric acid fumes are being collected at the North Works of the American Steel and Wire Company at Worcester, Mass.

An installation is being constructed for the collection of zinc oxide at the Works of the Chase Rolling Mill Company.

A large installation is under construction at the paper mill of the Brown Corporation at La Tuque, Quebec, Canada. This installation will recover soda salts carried by the draft from the special reduction furnaces in use at that plant.

Many other materials have been worked upon experimentally, but this incomplete list of commercial applications well illustrates the wide range of possibilities which these processes possess.

In closing, I merely wish to touch upon two features of the processes which present particular interest, as they open new fields of industrial development and modification of present methods in industrial practice.

The first is fractional precipitation with temperature control. The mere fact that the Electrical Precipitation Processes can effect a complete separation of suspended matter from gases at various temperatures, at once opens the possibility of separating two or more volatile substances from each other, provided such substances condense at different temperatures, or of separating a volatile substance from a non-volatile dust; for example: should it be desired to separate arsenic from a copper-bearing flue dust, all that will be necessary is to pass the gases through a treater at a temperature above the condensing point of the arsenic and precipitate the copper-bearing flue dust; then, should it be desired to collect the arsenic, the gases can be cooled by radiation or through admission of cold air to a temperature at which the arsenic will form a fume, the gases then passed through a second treater in which the arsenic can then be precipitated and collected.

This problem has been operated successfully at Anaconda and a permanent installation is now under construction at that smelter. In the tests, the ordinary smelter flue dust was heated in a Godfrey Roaster to drive off the arsenic. In the process of heating, considerable dust was carried along with the furnace gases. These gases were then passed through an electrical treater while hot and all of the dust precipitated. The gases were then cooled by the admission of cool air and the resultant fume of arsenic precipitated in a second treater. By this method, arsenic was collected as pure as 99.8 per cent As_2O_3.

This problem is of particular importance at Anaconda, where it is proposed to collect all of the fume now escaping from the main stack. The large amount of arsenic in the fume makes it imperative that the arsenic be eliminated from the flue dust before this is returned to the furnaces in order to prevent an arsenic circulation between the furnaces and the precipitator and an accumulation of arsenic beyond a controllable limit. It is proposed to eliminate the arsenic by the method just described.

Another interesting application of the same principle is the separation of sulphuric acid from flue dust,—for example in roaster gases, which always carry some flue dust and usually carry considerable SO_3 resulting from the conversion of the SO_2 through catalysis by the iron oxide in the furnace. To obtain this acid it should only be necessary to remove the dust from the hot roaster gases, then cool and humidify the gases and collect the remaining mist of sulphuric acid. Investigations upon this problem are now in progress in the Southwestern territory, it being desired first to raise the conversion of SO_2 to SO_3, in order to make a larger amount of acid available.

The advantages of such series treatment will immediately be apparent in connection with such processes as the volatilization of metals for recovery of such metals from low grade or complex ores. Such series treatment will not only allow of recovery of the valuable constituents, but opens possibilities for their concentration as well. Experimental work in this field is in progress, but this has not advanced sufficiently far to permit of published statements.

The second new departure is the precipitation of gaseous constituents. This is made possible, in certain instances, by intimately mixing with the gases finely divided materials of such nature as will react with or absorb the gaseous constituent which it is desired to remove, then precipitating the suspended particles which will then carry with them the absorbed or combined gas. An interesting application of this process has been made at the Hooker Electrochemical Works at Niagara, New York, in the bleaching powder department. The absorption towers, in which the chlorine is absorbed for the manufacture of bleaching powder, formerly did not effect a complete absorption and small amounts of chlorine were carried into the atmosphere and constituted a nuisance. Hydrated lime dust is now blown into the flue carrying the exit gases. This dust absorbs the chlorine, and the lime dust, together with the

absorbed chlorine, is separated from the gases in an electrical treater. This apparatus has been in operation for over a year, and has given entire satisfaction. About thirty thousand cubic feet of gas is treated per minute and the chlorine effectively removed so that the exit gases are now absolutely non-irritating.

Such combination processes will without doubt prove of value in various chemical industries in simplifying many processes where large volumes of gases must be brought into intimate contact with solid or liquid reagents.

Some views will now be thrown upon the screen illustrating a few of the interesting features of this work.

THE FLEMING PATENT DUST-COLLECTING SYSTEM

By W. C. HANNA, Chemist, California Portland Cement Company, Colton, Cal.

Read at the Los Angeles Meeting, August 18, 1915

As visitors pass out of the large acreage of orange and lemon groves owned by the California Portland Cement Company, and come within closer view of the splendidly equipped mill at the foot of Slover Mountain, those familiar with the general appearance of cement manufactories notice a decided difference in this one. There is something lacking which is common to the industry,—or has been in years gone by. There are no kiln and dryer stacks, with their objectionable trail of dust and fumes.

How it is possible to have such a condition in a factory of this size is explained by the buildings at one side of the plant, from the end of which large volumes of water vapor are pouring. These buildings and the machinery connected with them constitute the Fleming Patent Dust-Collecting System, which is receiving much attention from cement manufacturers throughout the United States, and back of which lies a history of interest to all connected with the cement industry.

Orange growers in the vicinity of Slover Mountain began to complain in 1909 about dust emanations from the kilns and dryers of the cement plants operated at Colton. At that time the new or largest plant was one of the most modern in the United States and was considered by cement manufacturers a clean plant, and as there had never been any recorded injury to people or vegetation in the neighborhood of cement mills, the orange growers' complaints and threats were believed to be without grounds, but serious enough, however, to warrant an extensive line of investigations and experiments with all known methods for capturing the dust.

These investigations were continued with zeal, but nothing of sufficient effectiveness was found. In the meantime the orange growers, not being satisfied with the efforts of the cement company, brought suit against it, and, in the trial during July and August of

1910, expert testimony from many parts of the world covered much of the field of cement manufacture, dust-collecting devices, and agriculture as practiced in the vicinity of Colton.

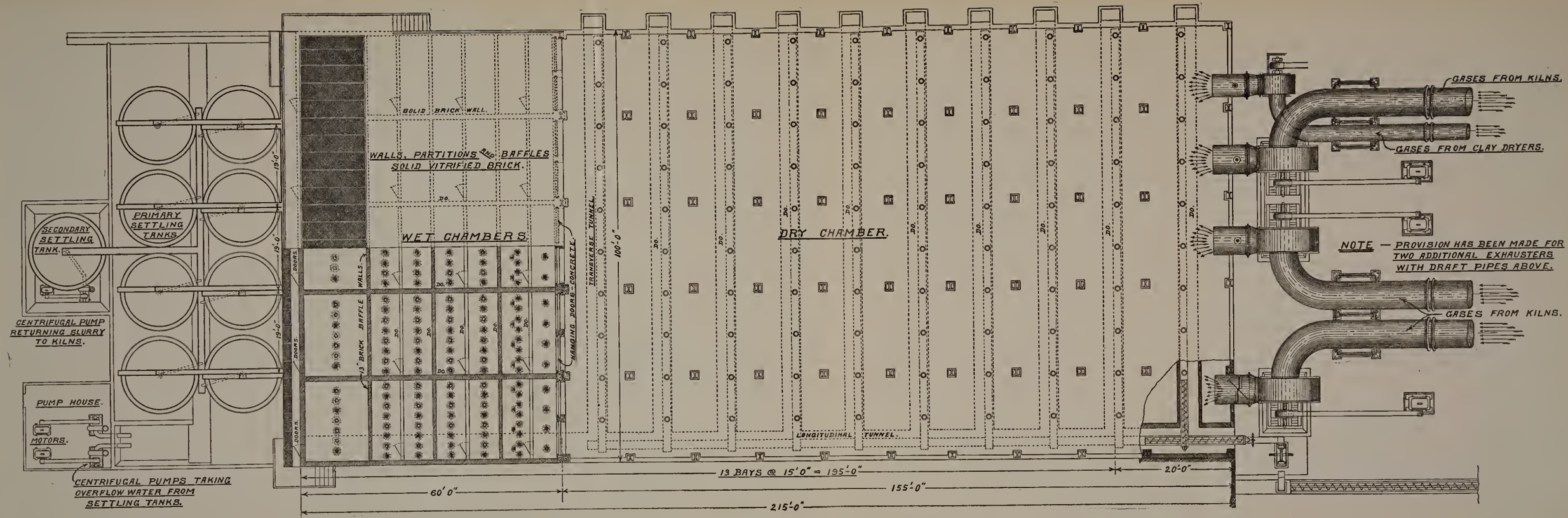
The Superior Court granted the orange growers an injunction in April, 1911, which became effective in June of that year, but by that time experiments at the old cement plant had proved so satisfactory that Mr. T. J. Fleming, Secretary and General Manager of the company, had most of the material on the ground for constructing his dust-collecting system on a practical scale for 5 rotary kilns 7½ feet in diameter and 120 feet long. By September, 1911, the first kiln was operating to the dust house and, shortly afterwards, all of the kilns were operating at full capacity with the Fleming System. Meanwhile, throughout the mill, a campaign against dust was made, resulting in all grinding machines, elevators, and conveyors being made practically dustless.

The orange growers were not yet satisfied with the efforts of the Cement Company and brought suit for contempt of court. The evidence was such that the court was not satisfied, so he appointed Dr. R. E. Swain, of Stanford University, as an impartial expert to make an examination of the system and report to him.

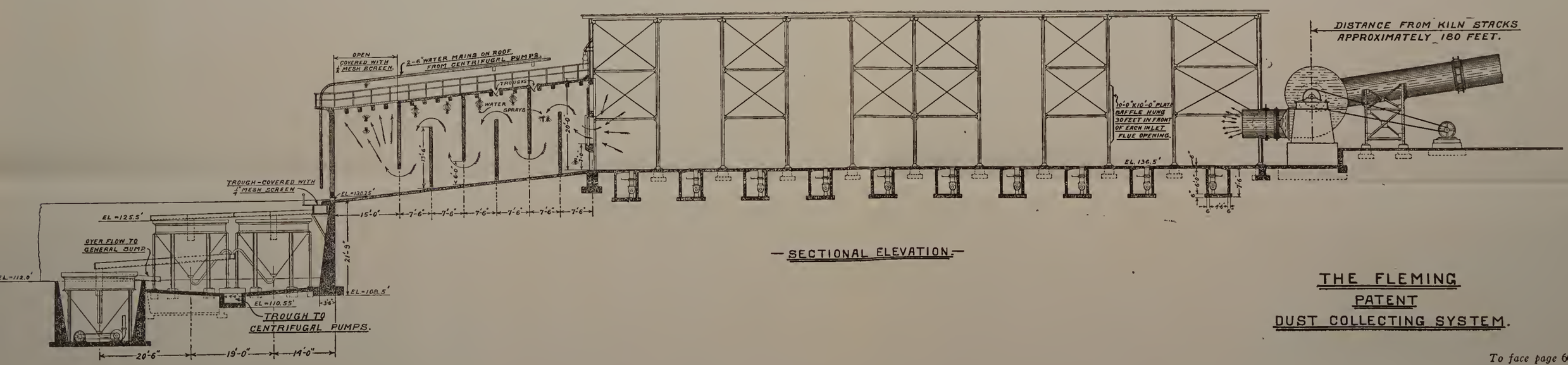
Dr. Swain's very complete investigations were made in February, 1912, and the report, which he made shortly afterwards, was so favorable that the court dismissed the case, stating that the plant, as operated, was not a nuisance and was not being operated in contempt of court.

This same system of dust collecting has been in continuous use since that time and has proved to be, not only an efficient means of capturing the dust, but also to be more than self-supporting, there being a saving to the company in the dust captured, better output per barrel of fuel oil, and less shut downs than before the Fleming System was in operation.

Very briefly, the installation consists of normal rotary kilns using dry process and oil for fuel. The draft for the kilns and dryers is produced by fans sucking at the end of separate flues. Instead of discharging the gases into the atmosphere, the same exhauster fan blows the dust and fume into a large chamber known as the dry-dust settling chamber, where the velocity of the gases is reduced about 90 to 95 per cent, resulting in a large amount of dust being deposited. The extremely fine dust which does not settle, and the gases then go to the wet washing chambers, where the gases are



— SECTIONAL PLAN. —



— SECTIONAL ELEVATION. —

THE FLEMING PATENT DUST COLLECTING SYSTEM.

To face page 66.

forced up and down several times while following a serpentine course through a system of seven baffle chambers, and the last of the original so-called cement dust is captured by sprays of water which are in each chamber. These sprays of water also bring into solution much of the gases, lime, and alkalies. In connection with both the dry and the wet chambers there are means provided for the removal of the captured dust to the cement kilns.

This paper will describe a unit in connection with three kilns 8½ feet in diameter and 150 feet in length with a capacity of 31

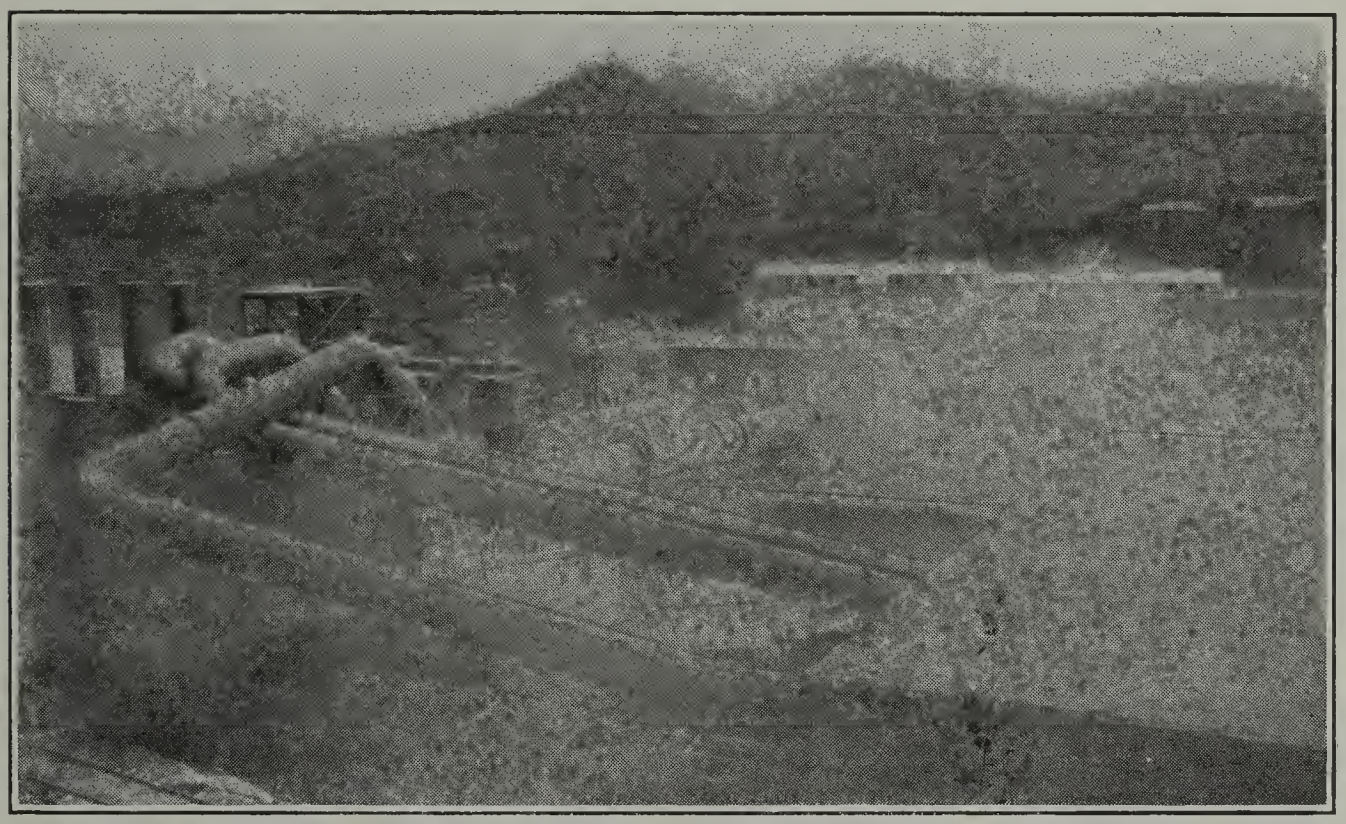


FIG. 1.—Three Kilns 8½ feet by 150 feet and flues leading to fans. The clay dryer flue is seen below the three large flues. Part of dry dust chamber shown in lower right-hand part of picture.

Sawed off stacks, with seals on top, for five kilns 7½ feet by 120 feet, are seen in the extreme left.

barrels of clinker per kiln hour, or about 2200 barrels per day, also one clay dryer which handles all of the clay used at the plant. This is the third large unit installed at Colton, each new unit, as installed, having a few improvements over the preceding one. The house has capacity for two more kilns of this same size.

The fans which produce the draft in the kilns are located at the end of what would normally be the stacks to the kilns, but which in this case are about 180 feet long and which, instead of being perpendicular, first rise from the stack base at the feed end

of kiln, then curve over and slope downward towards the fans. Each kiln is provided with a separate flue, fan, and motor, so that the operation of any one kiln is independent. The flues are 6½ feet in diameter, lined with fire brick for the first 20 feet, and they are provided with the necessary expansion joints.

The fans are of special exhauster type made by the B. F. Sturtevant Company. They are 5 feet wide and 10 feet in diameter, equipped with water-cooled bearings and operate at a speed of about 145 revolutions per minute, each fan being driven by a 40

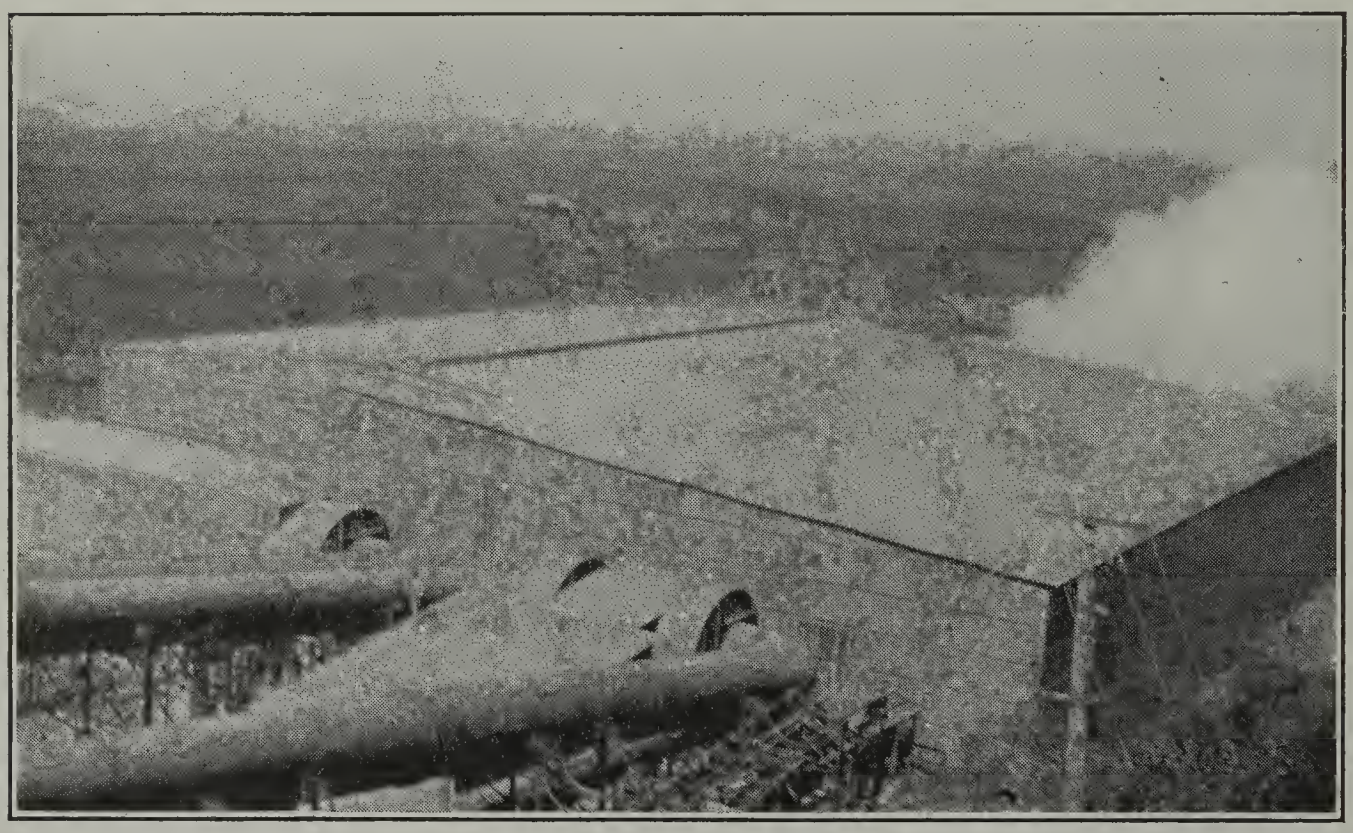


FIG. 2.—The Fans with part of flues, also dry dust chamber, and water vapor pouring from the Wet Baffle Chambers. The roof and one end of the second unit that was built can be seen at the left of third unit.

H.P. motor, although only 11.7 H.P. is required, except when the fan is first started. During the past year of continuous service there has not been a single hour lost due to fan trouble.

The results obtained by the kilns determine the speed at which fans are to be operated. Sometimes it is found to be desirable to give the kiln more draft, and the fan is operated at a faster speed, while at other times the reverse is true. The ease with which the draft in the kiln can be regulated is of great assistance in the economical operation of the rotary kilns.

A Thwing pyrometer is used in connection with the installation, the thermo-couples being located in the flues near the fans, and the

recorder in the kiln room where the cement burners can regulate the fires, keeping the temperature at the fans not higher than 900° F. This, together with the perfect control over the draft and of the speed of the kilns, makes the condition ideal for the manufacture of Portland cement clinker. The draft, induced as above, has proved to be far easier to control than a stack draft, the life of the kiln lining is almost permanent, provided kiln is not allowed to get cold, the ring formation reduced, and the clinker produced more uniform in quality.

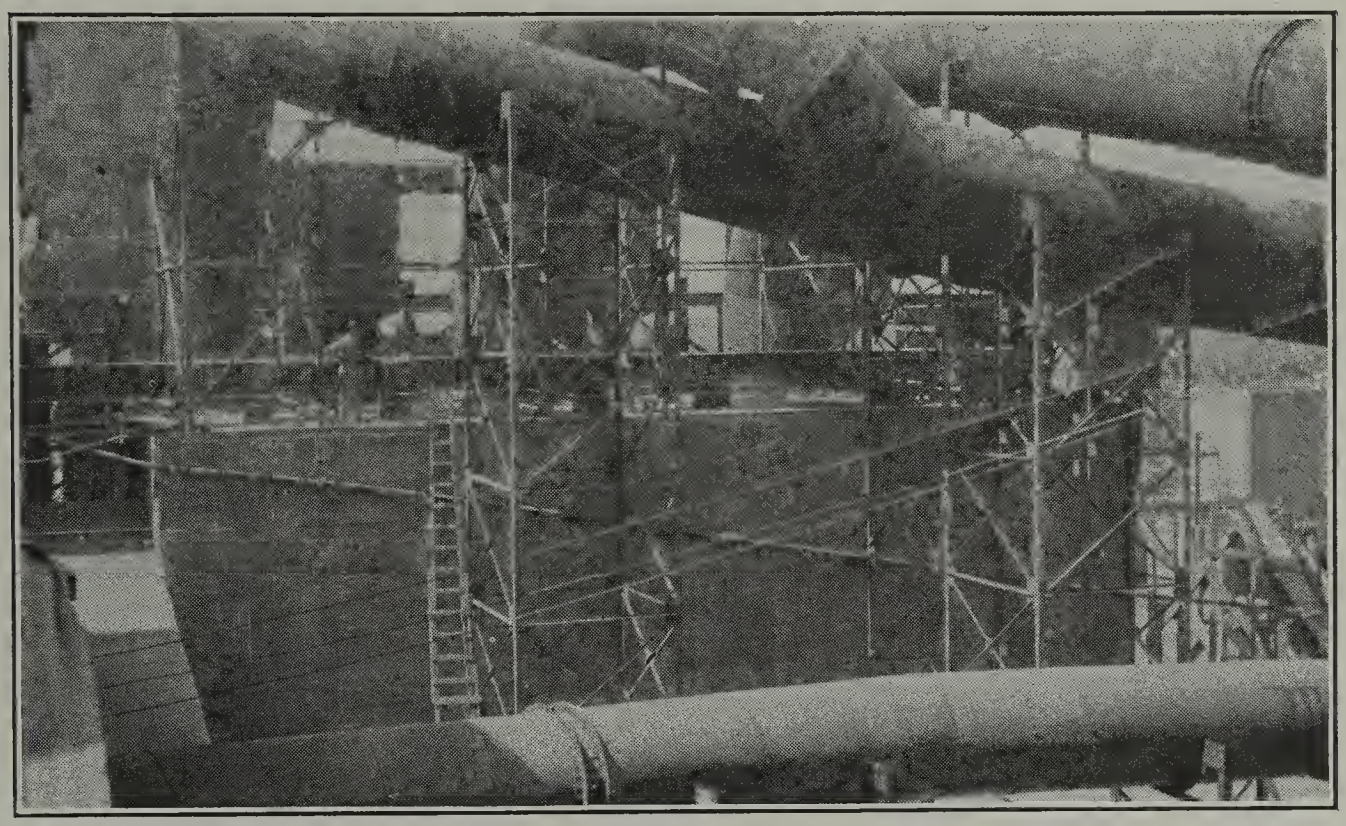


FIG. 3.—The Kiln flues leading to the Fans. The flue at bottom of picture, leads from the Clay Dryer to the Dust House.

The discharge from the fans is just about the same as from an ordinary kiln stack, only the blast is horizontal instead of perpendicular and at an elevation that is convenient for treating the gases laden with dust in the dry dust settling chamber. This chamber into which the fans discharge the gases is 155 feet long, 100 feet wide, and 31 feet high. It is a steel frame structure, with sides and roof covered with corrugated galvanized iron in order to promote radiation of heat. There are no barriers to a free passage of the flue gases within this chamber, except a set of baffle plates about 10 feet wide extending across the chamber in a line about 30 feet in front of the inlet flue openings. The temperature of the

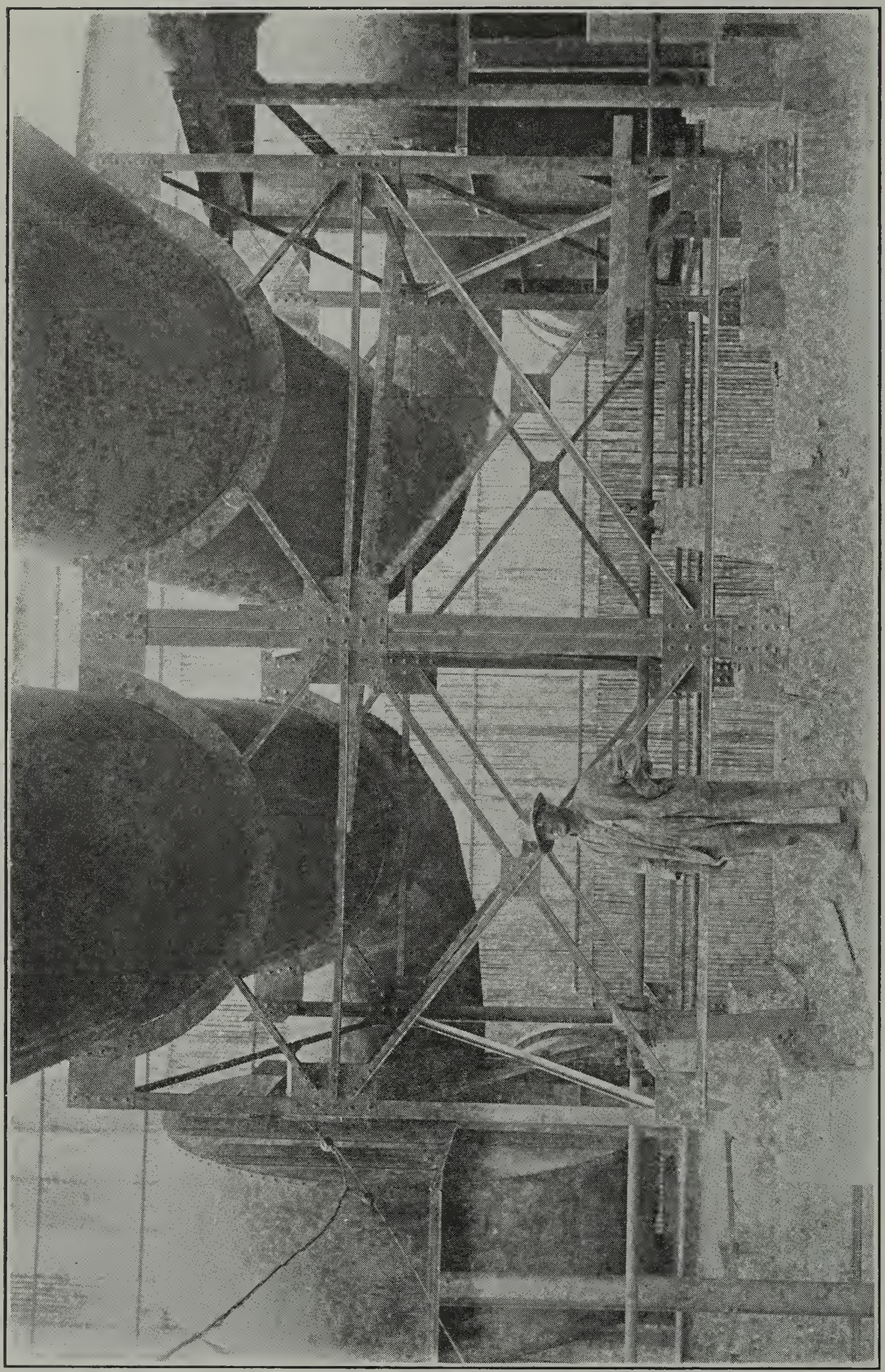


FIG. 4.—Fans and Flues leading to them from Kilns, and the Flues connecting Fans with dry dust chamber shown in the background.

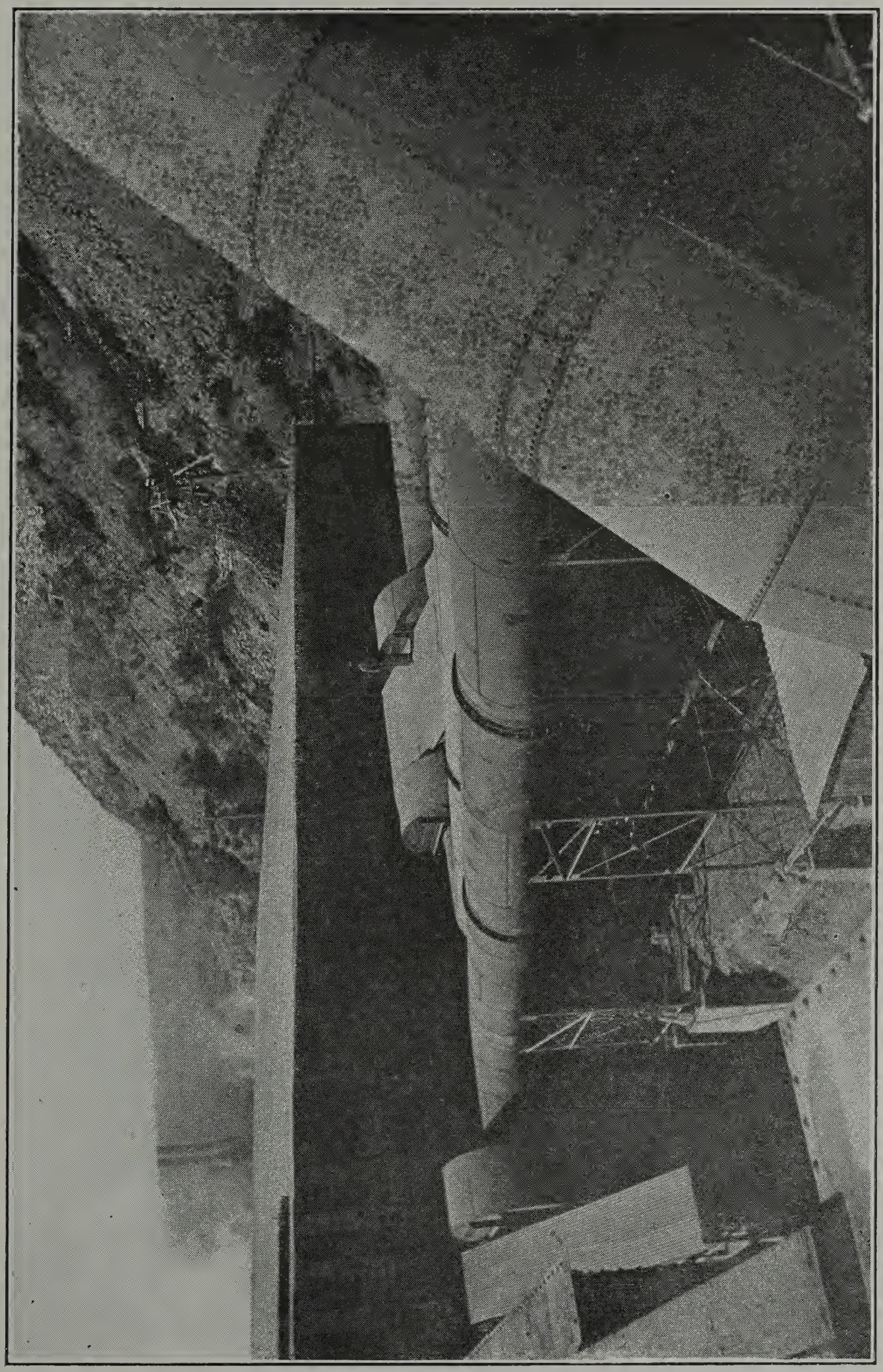


FIG. 5.—View of Flues, Fans, and Dry Dust Chamber taken from a point just above exit from Rotary Kilns. Expansion joints on one flue can be seen.

gases as they go to this chamber is 700° to 900° F., and on emerging from the same the temperature is 300° to 400° F. Due to this reduction of temperature, and to the large area of the house there is a 90 to 95 per cent reduction in the velocity of the flue gases, resulting in about two-thirds of the suspended dust particles or about 30 to 40 tons of dust per day being deposited in this dry chamber. There are 10 cross tunnels beneath the floor of this department, and in each tunnel there is a screw conveyor with steel troughs and 10 spouts, with gates, leading from the floor above into the conveyor

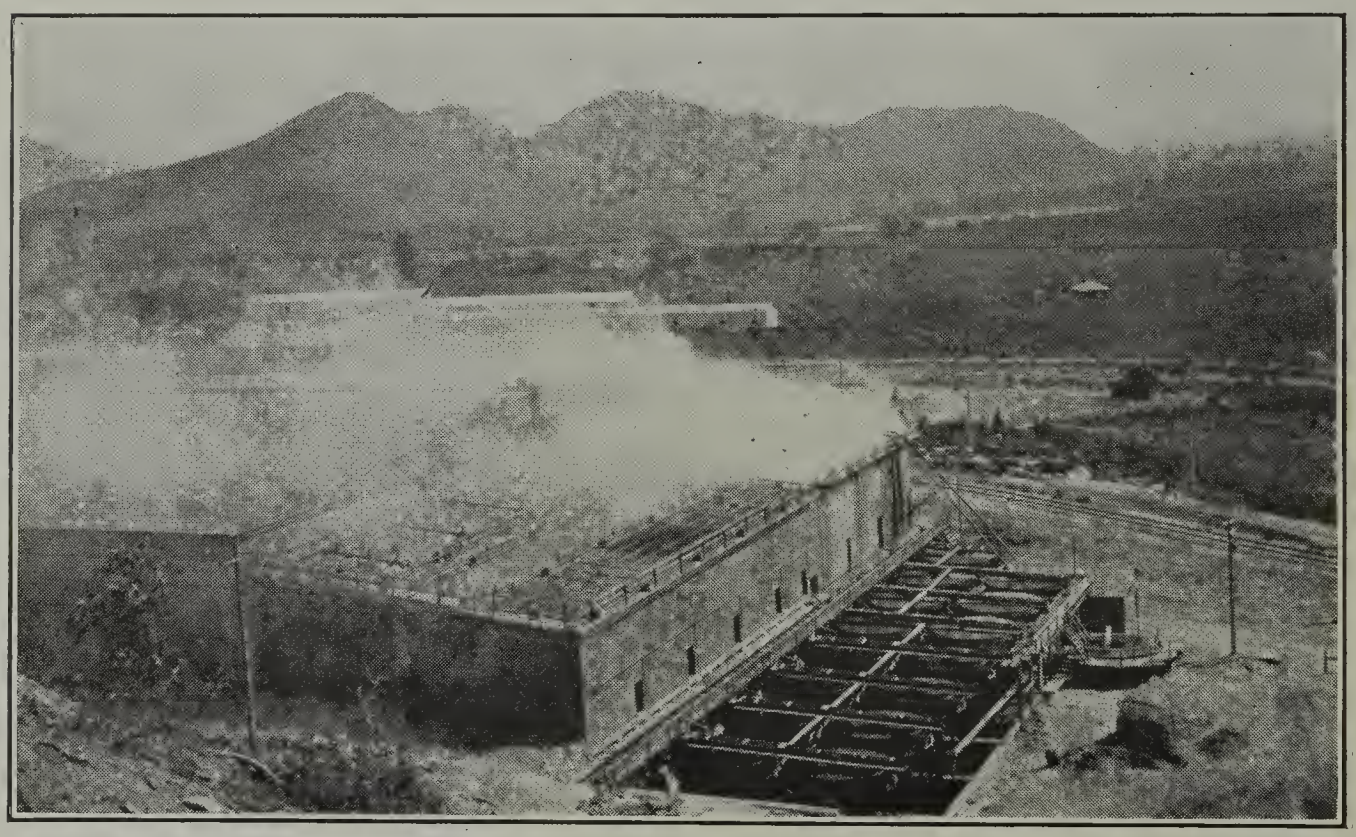


FIG. 6.—Dry Chamber at the left, then the Wet Baffle Chambers, and then the Settling Tanks.

for drawing off the dust. Each of these cross tunnel conveyors discharge into the conveyor running in the main tunnel, and it, in turn, connects with a conveying system which carries the dust to a bin in the raw mill building. The dust is drawn from this bin and properly mixed with the material being fed to the kilns.

The gases with the remaining dust, go to the wet baffle chambers, which is the same width as the dry chamber and 60 feet long. The framework is of steel, the sloping floors are of concrete, the walls of brick and concrete, and roof of expanded metal encased by concrete. It is divided into five separate compartments, each 60 feet long and 20 feet wide. Each compartment receives the gases from the

dry chamber through two openings, 6½ feet by 9 feet, which may be closed by means of hanging concrete doors operated vertically from the roof. Only three of these compartments are required and the two not in use can be kept in reserve in case any of the others should require new sprays or other work done on them. Each of these compartments has six transverse baffle partitions alternately rising from the floor and descending from the roof, leaving 6-foot transverse openings through which the gases are forced, over the first baffle and under the second, and so on until they pass under the sixth baffle, emerge into the exit chamber, and through the roof, which is made of ½-inch mesh wire screening. The actual area of exit openings for each compartment is about 135 square feet. The velocity of the gases about 250 feet per minute.

Each baffle section in each of the five compartments is provided with a set of water sprays. The return water from the settling basins is used in all of the sections except the last ones. Each spray with return water is adjusted to carry about 12 gallons of water and each fresh water spray delivers about 6 gallons per minute. In these wet baffle chambers the remaining one-third of the dust in suspension is removed and the temperature of the gases reduced to about 125° F. at the exit.

The water, with its load of dust, falls to the sloping floor and runs to the end of house, where it falls into a screen-covered trough extending the entire length of the end wall of the wet baffle chamber. Lateral troughs lead from this to the center of each of the eight primary conical, steel, settling tanks, 16 feet in diameter. The overflow from these, being almost free from suspended matter, falls through the open air, in order to cool it, to the reservoir below, from which it is pumped as return water at about 100° F. by centrifugal pumps, back to the sprays. The thin slurry from the bottom of the conical primary settling tanks is syphoned through gooseneck pipes to a common trough, which leads to a secondary conical settling tank. The clean overflow from this also goes to the common collecting reservoir, but its thick slurry, containing about 20 pounds of solids per cubic foot, is pumped to the slurry tank above the kiln stack bases, from which it is continually fed to the rotary kilns.

The amount of water required to operate the Fleming System is much less than at first would be expected. The fresh water need not exceed 75 to 100 gallons per minute, and it has been found

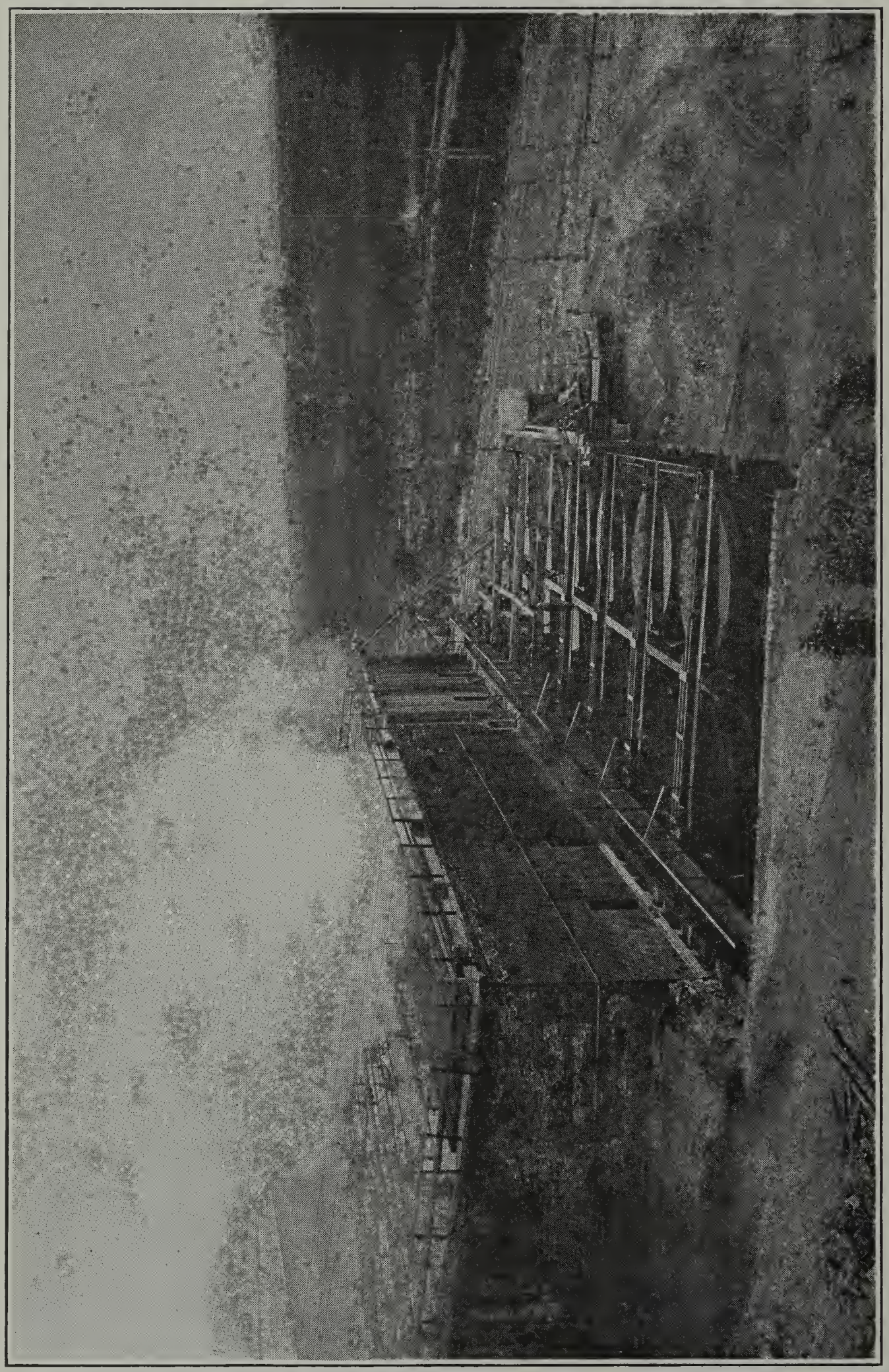


FIG. 7.—General view of Wet Baffle Chambers with cloud of water vapor pouring from exit. Eight of the Settling tanks serve unit No. 3 while seven serve unit No. 2. The single Secondary Tank serves both units.

desirable to add this in the form of coarse sprays in the exit chamber, above the screen to the same, and in the baffle chamber just before exit chamber. The greatest part of the washing is done by the circulating water, which amounts to at least 1000 to 1200 gallons per minute. The heaviest sprays of return water are located in the second baffle chamber after leaving the dry chamber.

The amount of dust captured each day in the dry dust chamber is about 30 to 40 tons, while about 15 tons is captured in the wet baffle chambers. Where only rotary kilns are operated in connection with the dust-collecting system, the proportions of calcium

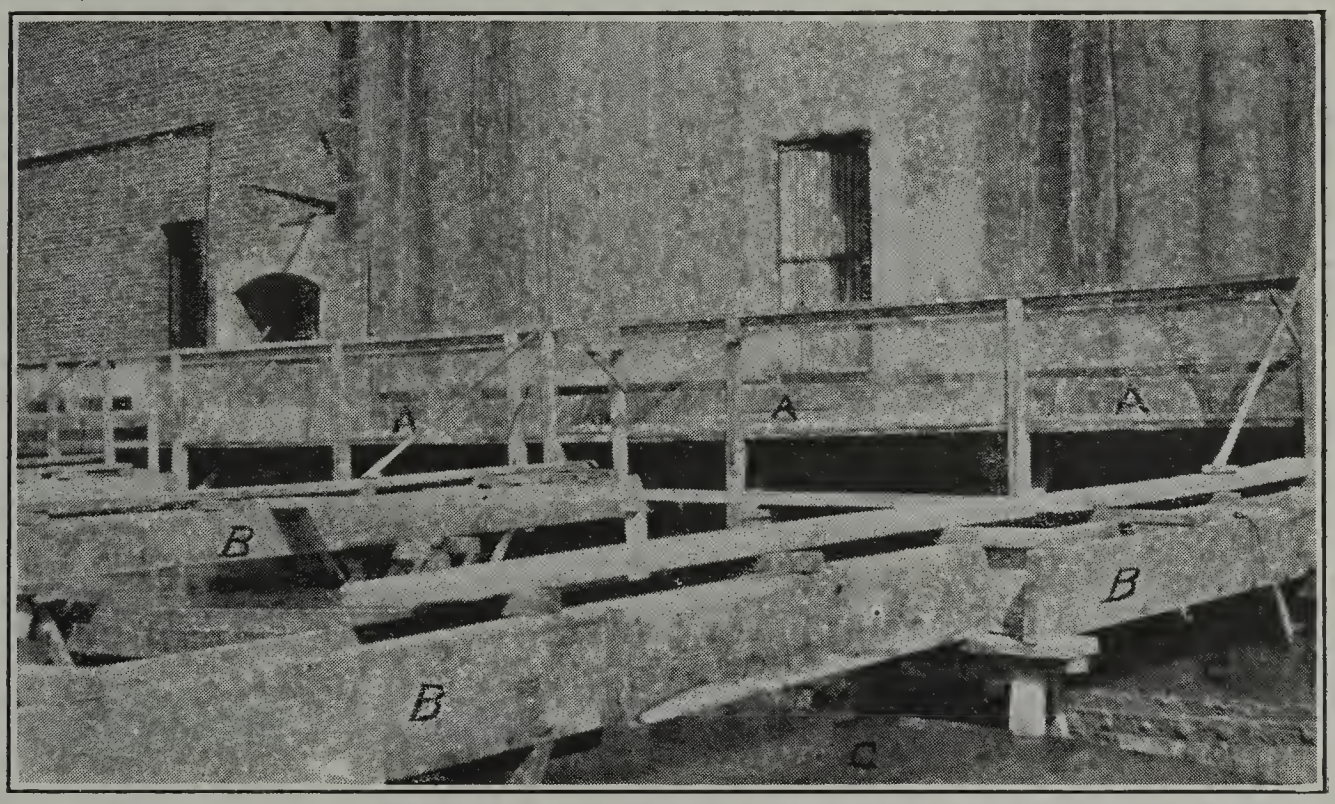


FIG. 8.—Exit Water. *A*, water with load of dust falling from sloping floors, into main trough. *B*, lateral troughs over settling tanks. *C*, surface of water in settling tanks.

oxide, silica, and alumina found in both the dry dust and slurry are found to be such that they can be returned to the kilns without special attention being given to them. Where dust from dryers, such as clay dryers, is also collected in the same system the dust will contain an excess of clay and it must be returned with proper care. At the Colton plant, the dust is used so as to balance any irregularities in the composition of the raw mix as it goes to the kiln feed bins.

The method of using the dust will probably be of interest, so I will briefly tell you how it is blended.

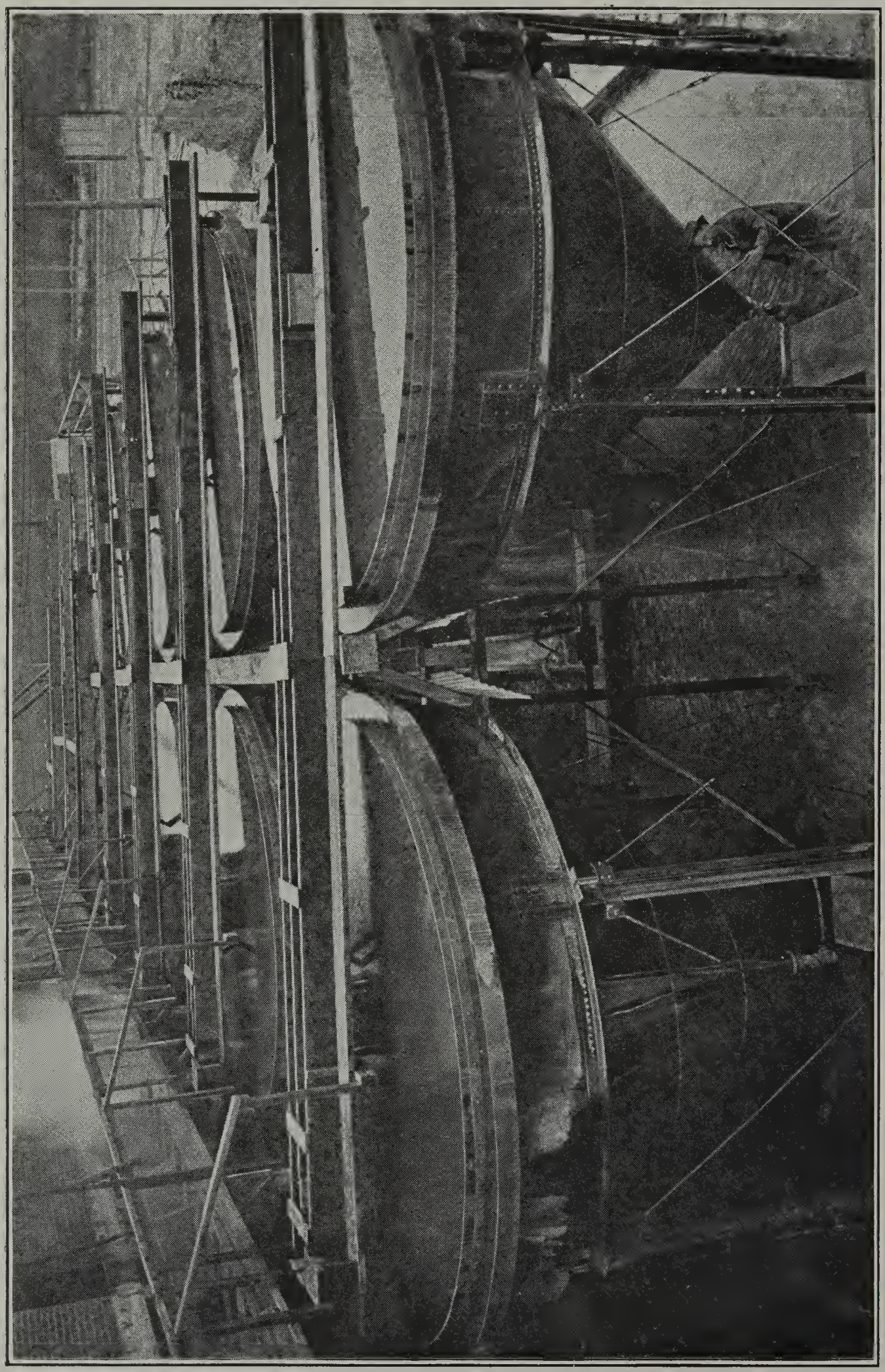


FIG. 9.—Settling Tanks with Syphons or Gooseneck Pipes extending from bottoms to common trough. General Sump below tanks.

The rotary kilns and the dust-collecting system are in operation twenty-four hours each day, while the clay dryer operates at night long enough to fill the empty clay bins. The slurry from the wet baffle chambers, after being thickened in the tanks, is pumped about every hour above kiln stack bases to a tank holding almost one day's run, and the slurry kept in agitation by compressed air. The 100 spouts under the dry dust chamber are opened daily, only on the day shift, and the dust conveyed to a bin of almost one day's capacity in the raw grinding department.

The amount of dust deposited in the collector from the kilns is very uniform, and from the amount of clay used one day it can be closely estimated how much clay will be deposited in the chamber that night to be mixed with the kiln dust for use the next day and night.

The raw mix, as proportioned at the scales, is made of such composition that the dust must be added to it in order to give a suitable composition. The dry dust can be added to the ground raw mix at any desired speed, and from 1 to 15 raw mills can operate without causing inconvenience. When everything is normal, the miller operates the dust feeder at a specified speed for each different number of mills that he may be operating, but in case the raw mix, as tested in the laboratory, is found to require a little more or less clay, the laboratory orders the dust feeder to be speeded up or reduced sufficiently to give the desired mixture. As the dry raw mix runs into the kilns, a small stream of the well-mixed slurry from the slurry tank runs by gravity into the kiln.

The dust captured in the dry dust chamber is very fine, practically all passing a No. 200 sieve and about 97 per cent passing a No. 300 sieve. Both this dust and the extremely fine dust captured in the form of slurry have much more sulphur, potassium, and sodium than the raw mix, but after a few returns to the kilns they do not show any further increased percentages of these elements.

The water used in the wet baffle chambers very rapidly becomes heavily laden, chiefly with sulphur compounds of potassium, sodium and calcium, and when more than half a pound per cubic foot is found, some of the water is taken out and replaced by fresh water in order not to cause trouble with the sprays. Plans are being made to recover the potash.

The dust which is discharged into the air from the exit to house amounts to about 1 ton per day. This dust bears no resemblance to the original cement dust, it being for the most part sulphur compounds of potassium, sodium, and calcium and about 88 per cent to 94 per cent soluble in water. This dust is produced by the draft drawing out the fine sprays of water from the wet washing system, much the same as the wind carries inland the salt water spray from ocean breakers.

The Fleming System requires very little labor. The regular oiler looks after the fans in addition to the regular machinery. The raw mill operator regulates the dry dust feeder and the kiln feeder looks after the slurry when it requires attention. The man who operates the water pumps for entire cement, lime, and crusher plants also operates the slurry pump and return water pumps. One man is required for nine hours per day to draw the dry dust from the dry dust chamber and another man looks after the wet washing system each day in order to keep things in proper condition. This latter man is at times aided by pipe filters to repair pipe lines and laborers to help clean the compartments.

The power consumption is reasonable, not exceeding 2000 kilowatt hours per day, of which 57 per cent is used on the return water pumps.

The cost of placing the Fleming System in an old plant would depend upon the general layout of the plant, the amount of room available, and type of construction. In a new plant the apparatus can be placed with ease and at minimum cost.

In concluding my remarks with the customary contrast of results "before and after using," it is impossible to deal exclusively with the unit used thus far in this paper, as that unit has always operated with the dust collector in connection. Therefore it will be necessary to take results obtained with one clay dryer and five kilns, 7½ feet in diameter and 120 feet long, which are operated for about 2½ years with normal practice and then for the same length of time with the Fleming System.

With this dust-collecting system in use there was obtained:

First: About 24 per cent more clinker per barrel of fuel oil consumed.

Second: About 5 per cent more clinker produced per hour of kiln operation.

Third: About 2 per cent more actual operating time of kilns.

Fourth: Over 7 per cent less raw materials required for manufacturing a barrel of cement.

Fifth: The quality of the output was improved.

Sixth: Dust from dryers and kilns collected and the nuisance abated.

DISCUSSION

Mr. BARUCH: It being our usual custom to open for discussion all papers, it will probably be wise to take up the matter now while the subject is fresh in our minds. If any one wishes to discuss the question Mr. Hanna will be glad to entertain any question and to give any further information that may be desired.

Mr. HARDIN: What is the value of this dust compared with the expense of getting it out? You say it saves about 7 per cent in raw material; now, what is the saving in comparison with the cost of getting out the dust?

Mr. HANNA: Do I understand you to mean, is this dust of value? Yes, we find this dust is a paying proposition; not only do we use the dust at the present time, but we have sold a great deal of it for paving dust at a higher cost than taking it out. We have sold some for fertilizer (there is quite a field for that an account of the potash which it contains). The dry dust will have from 1 to 5 per cent of potash, and 10 to 12 per cent of calcium sulphate. The circulating water contains at least 0.5 pound of solids per cubic foot in solution, and of this as much as 30 per cent is potassium sulphate.

Mr. BARUCH: I suppose the greatest value lies in obviation of dust irrespective of the value of the slurry itself?

Mr. HANNA: We are operating out there now under an injunction, and if we should operate with normal practice we would have to shut down, so the cost would be no item. Even if we lost money it would be a necessity.

Mr. F. J. CARMAN: Is it intended to publish this paper? If so where?

Mr. BARUCH: The paper will be published in the Transactions of the American Institute of Chemical Engineers, and possibly in the *Metallurgical and Chemical Engineering Journal.*

Dr. POTTER: Any improvement on the citrus industry in the neighborhood?

Mr. HANNA: Yes, most of the groves in the vicinity of Slover Mountain at the time we installed the system were owned by orange growers who brought suits against us. They were neglected and not taken care of. Finally we negotiated and purchased about 100 acres of orange groves around the plant, and at the last Annual Orange Show in San Bernardino we took six prizes, several first, second and third prizes, and the fruit is very good in quality. The groves have improved in condition, but that is not due to abating the dust nuisance, but to expert orange growers taking care of the groves.

Mr. BARUCH: Any further discussion?

Mr. CHURCH: Mr. Chairman, I would like to ask what is the maintenance and depreciation in the plant?

Mr. HANNA: That is hard to say, because when we put in the first collector, it was put in in a great rush, we had nothing to go by and were experimenting. About the time we completed it we tore it down and put in a larger one. We put in a larger one right away because we could not afford to shut down and could not run with normal practice, due to the injunction. About that time we decided to increase our capacity and we put in a third. In doing this we kept tearing the houses down and rebuilding and I do not know the depreciation. As I said in my paper, the fan trouble was very little. We did not lose any time to speak of on account of fan trouble, and that is the main thing.

Dr. POTTER: Any pump trouble?

Mr. HANNA: Very little pump trouble. The water in the circulating chamber is pumped through hot, but it does not cause any trouble. We have had some trouble with scale in pipe. We use centrifugal pumps.

Dr. POTTER: Anything abrasive in the slurry?

Mr. HANNA: The slurry is extremely fine, most of it will pass a 300-mesh sieve, and is not abrasive.

THE THIOGEN PROCESS FOR REMOVING SULPHUR FUMES

By S. W. YOUNG.

Read at the San Francisco Meeting, August 27, 1916

The Thiogen process was devised as a possible means of eliminating the deleterious sulphur dioxide from smelter fumes and converting it into free elemental sulphur as a useful product. The fundamental chemistry of the proposed process lies in the simple reduction of the sulphur dioxide to sulphur by means of carbonaceous or hydrocarbonaceous materials. In localities where natural petroleum is readily available, it, in some form or other, would be the most desirable material for the purpose. For the purpose of the present paper it will be assumed that petroleums are to be used for the purpose, and that their composition is sufficiently closely represented by the formula CH_2. The theoretical equation representing the reduction of sulphur dioxide by such hydrocarbon material is as follows:

$$3SO_2+2CH_2=3S+2CO_2+2H_2O \qquad (1)$$

This equation represents the theoretical maximum chemical efficiency which the process could attain under any condition. It will be seen that, working at this maximum efficiency, 28 tons of hydrocarbon would produce 96 tons of sulphur. This is of course taking no account of hydrocarbon used as fuel or for any other purpose.

The patents owned by the Thiogen Company cover two general methods of carrying out the above mentioned reduction of sulphur dioxide, one known as the "Dry Process," and the other as the "Wet Process." The experimental developments of the two processes have been of wholly different character, and the experiments have been carried out independently. The two processes, together with the results accomplished, will therefore be discussed separately in this paper.

THE "DRY PROCESS." If one attempts to carry out the reduction of sulphur dioxide by means of hydrocarbon vapors in combustion tubes, very complex and incomplete reactions occur, which result in considerable evil-smelling vapors and much unattacked sulphur dioxide. Even at temperatures too high to be available for practical operations, the reaction is too slow to be of any use. In the investigations leading to the Thiogen patents, a number of satisfactory catalysers were found. These are all compounds of such metallic elements as yield sulphides readily by reduction of sulphates or sulphites, and whose sulphides are infusible and readily converted back to sulphites or sulphates by the action of sulphur dioxide. Such sulphides as those of calcium, barium, and magnesium seem to give the best products for this purpose. A little thought will make clear the probable catalytic action of the compounds of these metals.

If we start with say calcium sulphate and treat it at elevated temperatures with hydrocarbon vapors, it becomes reduced to calcium sulphide. If, still at elevated temperature, the sulphide be treated with sulphur dioxide, the following equation represents the reaction which occurs:

$$CaS+2SO_2=CaSO_4+2S \qquad (2)$$

A few experiments in the laboratory very soon demonstrated the fact that the reduction of calcium or other sulphate to sulphide and its reconversion to sulphate and free sulphur by means of sulphur dioxide could go on readily side by side. That is, if sulphur dioxide mixed with hydrocarbon vapors in the proper proportions is passed through a heated combustion tube containing fragments of calcium sulphate, the reduction of the sulphur dioxide takes place with great ease and rapidity, and the products are mainly sulphur, carbon dioxide, and water vapor. Little or no carbon monoxide is found unless excess of hydrocarbon is used.

This is the fundamental principle of the Thiogen "Dry Process," and we shall now proceed to a brief description of the attempts to develop it to a commercial process.

The Penn Mining Company, with a smelter located at Camp Seco, California, placed at our disposal ground space, gases, materials, and money for a very considerable series of experiments on a commercial scale, and our thanks are due to all the officials

and employees of that company for their helpful attitude. After one or two series of experiments with various forms of apparatus, experience seemed to point to a vertical reaction chamber as best for the purpose. This was constructed of large iron pipe 5 feet in diameter and 20 feet high. It was lined with fire brick, and four stationary hearths were built in. On these hearths was placed the contact material. This was made up of plaster of paris, which was slopped and allowed to set, after which it was thoroughly dried and broken into lumps about as large as the hand, so that when installed on the hearths it made loosely porous masses, affording good mixing and contact for the reacting gases. Each hearth was provided with manholes for cleanout and replacement, as well as with tubulations for gas sampling throughout the period of operation. A system of pyrometers was also installed whereby records of temperatures on all the hearths could be obtained.

Below the fourth hearth were the intake for the roaster gases to be treated, and two crude oil burners. Two burners were used instead of one, to increase the range and accuracy of regulation. The roaster from which the gases were taken was an ordinary McDougal. It was provided, for our purposes, with a by-pass system and fan blower, whereby a part of the gases could be continuously returned through the roaster. We were thus enabled to get gases of fairly constant composition for sufficient periods of experiment, and under favorable conditions we were able to maintain a fairly steady flow of gas as high as 11 per cent sulphur dioxide, for sufficiently long periods to be useful for experiments.

In beginning a run, the procedure was to first start the oil burners, with air draughts, and to keep up the firing until the contact material on all hearths was a good bright red. The air draught was then cut down and the roaster gases admitted. Analyses were continuously taken from all the hearths. These showed at first complete reduction on the first hearth. After a time this hearth began to cool down and reduction was imperfect. The second hearth, however, showed perfect reduction for a time, when this also began to cool off, and so on until the whole apparatus went out of action. This cooling action could be ascribed to two causes: First, absorption of heat by vaporization of the oil; second, the oncoming roaster gases were too cold (they had been cooled to about atmospheric temperature by a scrubber in order to remove dust). An outside vaporizing chamber for oil was built, and while

this assisted somewhat, the same cooling as before occurred. A rather elaborate pre-heating apparatus for the gases was then designed, but unfortunately at about this time the company encountered difficulties with their mining operations which made it seem doubtful wisdom for them to continue financing the experiments. So the experiments were terminated. In the meantime considerable valuable information had been obtained. Without going into details this may be summarized as follows:

(1) Under favorable conditions the reaction between sulphur dioxide and hydrocarbon vapors in contact with the calcareous material is extremely rapid. We were never able to force the apparatus beyond capacity.

(2) The process does not offer any hope of working well with gases under 7 per cent in sulphur dioxide. At lower percentages than this considerable sooting occurs, which soon puts the contact mass out of commission.

(3) In order to operate successfully, the process will demand preheating of the gases. To just what temperature this preheating must go it is impossible to say in absence of experimental evidence. The calculated values do not indicate that it is likely to be an especially difficult matter.

(4) The dry process undoubtedly contains the elements of a successful commercial process for producing sulphur, under the condition that the plant producing the gases will operate for high concentration gases. Seven per cent sulphur dioxide is necessary, and the higher the percentage goes the better, as every drop in sulphur dioxide content means additional oxygen to burn out, and thus additional oil costs per ton of sulphur.

"The Wet Process. The Thiogen wet process proposes to accomplish the same end as the dry process, namely the reduction of sulphur dioxide to sulphur by hydrocarbon vapors or carbonaceous material, but it accomplishes this result in a far different way. It was the first of the two processes to be devised. The general procedure in the wet process is as follows:

(1) The sulphur dioxide is first absorbed in water in appropriate absorption towers. This operation takes place in accordance with well-known laws and needs no further discussion.

(2) This solution of sulphur dioxide in water is mixed and allowed to react with a paste or solution of a suitable sulphide. The most suitable sulphide for this purpose that we have found

thus far is barium sulphide. The reason for preferring this to the much less expensive calcium sulphide will be discussed later. When sulphur dioxide reacts with basic sulphides in the wet state, the processes which occur are rather complex. Considerable free sulphur is formed, and in addition, sulphites, thiosulphites and thionates of the metal used. The formation of some complex sulphur salts is a matter of little moment, since in the further operations they break down, and furnish their equivalent of free sulphur.

(3) As a result of the treatment described under (2) there is formed a sludge whose solid components are free sulphur and the sulphur salts of the metal used. If the treatment is properly carried out, these solids settle and filter with greatest ease, and the supernatant liquid is practically pure water, which may again be returned to the absorption towers.

(4) The solids of the sludge, after settlement and filtration are dried, and then raised to a temperature of from 450° to 500° C. In this way the complex sulphur salts are broken down and the total sulphur available as free sulphur is distilled off and condensed. The still residue consists of a mixture of sulphite and sulphate together with some sulphide under certain conditions. The sulphide is formed as a result of the well-known breakdown of sulphites into sulphides and sulphates at higher temperatures.

(5) The residual sulphites and sulphides are next passed through an appropriate furnace where they are reduced back to sulphide, and are then again ready to be brought into reaction with further quantities of sulphur dioxide solutions. There is thus accomplished a cycle of operations whereby nothing is used up but sulphur dioxide and reducing materials, for which there is produced an output of free marketable sulphur.

The reasons for choosing barium sulphide instead of calcium are chiefly as follows:

(1) Barium sulphide is readily and rapidly soluble in water, while calcium sulphide is not. Thus ease of intimate mixing and rapid reaction with the sulphur dioxide liquor is greatly favored by the use of the barium compounds.

(2) The sulphite, sulphate and the complex sulphur salts of barium are much more insoluble than the corresponding salts of calcium. This prevents the building up of any disadvantageous concentrations of these salts in the water used in the operation.

(3) The barium salts all crystallize anhydrous while the calcium

salts all carry water of crystallization in considerable amounts. This means a great saving in the heat demanded in process (4) of the cycle, namely the drying of the filtered sludge. If calcium salts are used, the preparation of the solids for distillation would demand not merely the drying away of adherent water, but also the driving off of large quantities of water of crystallization.

(4) The settling and filtering properties of the barium sludges are vastly superior to those of the calcium ones.

All phases of operation of the wet process have been worked out quite thoroughly by us in the laboratory, and all members of the cycle have been realized practically. The element which offers the greatest difficulty is the reduction of the still residues to sulphide. This has been accomplished satisfactorily, however, on a laboratory scale, and with the use of only very crude apparatus. At present, the plant of the U. S. Bureau of Mines at the Panama Pacific Exposition is carrying on a quite extensive investigation of the wet process on a scale much larger than we were able to handle. They have confined and amplified our smaller scale operations. I do not feel justified in personally discussing their work any further than this. The investigations are under the direction of Messrs. Duschak and Wells, and I am sure these gentlemen will welcome any of you, and explain more fully what they are accomplishing.

As to the relative merits of the two processes, the wet process has the great advantage of operating under present conditions of roaster and blast furnace operations, namely low concentration of sulphur doxide. On the other hand, I still firmly believe that wherever roasting for high concentration could be introduced, the dry process would prove the more economical for the production of sulphur.

At the present time the Thiogen Company is doing practically no commercial extension work, and is under no contracts to install or operate even experimental commercial plants. The most that could be done was to raise the money necessary to finance the experimental work at the Exposition. The company has always had to face a curious political or diplomatic situation, whichever you choose to call it, which has held up any very great progress. Those smelters which are operating under such conditions as to cause damage to the surrounding lands and crops are doing so largely through the inability of the people to convince the courts that damage is being done. This being the case, any co-operation on the

part of the smelters in the development of a process that is aimed primarily at alleviating a form of damage which is not admitted, would in a way weaken the position that they have already established. Things being as they are, and business being business, it would perhaps be unjust to blame the smelter people for their attitude. (applause)

DISCUSSION

The CHAIRMAN: This paper is open now for any remarks or any questions to be asked the author of the paper. I don't suppose it is necessary to ask now what Thiogen is. I think after reading those chemical reactions as most of us are capable of doing, that the question is answered as to what Thiogen is, but there are other more practical questions probably that may be suggested and if there are any questions to be asked, this is the opportunity. Are there any comments?

Mr. DRAKE: I would like to ask the Professor how dilute the gas is when he makes the extraction?

Prof. YOUNG: We have done all of our reckoning on 3½ per cent.

Mr. DRAKE: Any content at all in the exit gases?

Prof. YOUNG: We can always use a chaser on the end by which we take slight traces out. That is a perfectly feasible plan. You can always use a barium sulphide solution. Even without it you can reduce down to very low content without the cost being very burdensome.

Sec. OLSEN: That is, that water will take out to one-tenth of one per cent?

Prof. YOUNG: By proper operation.

Sec. OLSEN: You get, of course, no by-product of any value?

Prof. YOUNG: None except the sulphur.

Sec. OLSEN: Would that come anywhere near paying for the process?

Prof. YOUNG: I believe it would more than pay for it after the process is well established. I don't remember exactly how it figures out, but I think they estimate the current price of oil at a figure whereby we could produce sulphur at about $7 a ton by this process; it is around about that.

Sec. OLSEN: What does sulphur sell for?

Prof. YOUNG: The base price is $22.

Mr. BECKMAN: What concentration of gas was there?

Prof. YOUNG: Three and one-half per cent.

Mr. BECKMAN: With that you can produce sulphur for $7?

Prof. YOUNG: I would not say positively $7, but between $6 and $10.

Mr. WITHROW: Is that the Louisiana quotation?

Prof. YOUNG: London quotation.

The CHAIRMAN: Does the process whereby the sulphur is distilled off make any difficulty?

Prof. YOUNG: No. We have had no trouble. I don't think there would be the least difficulty. It would be preferable, of course, to wash it with inert gases. We have a tentative set of plans for a distillation apparatus.

The CHAIRMAN: You have an example of what was done with the Trent process in England.

Prof. YOUNG: Yes, they do a great deal there. I took this whole matter up with a chemist who had operated the process in England. They for a great many years have been operating the Chance recovery process in England and he was quite confident there would be no serious difficulty in any of those particulars.

Mr. SCHMIDT: In your sketch you show a gas cleaner. Is there any deleterious effect from dust?

Prof. YOUNG: Well, it clogs the material. It is necessary to keep the barium fairly free. If you get much alkali and silica in there will be fluxing.

Mr. SCHMIDT: No danger of poisoning?

Prof. YOUNG: No, it is not that. It is simply the effect on your barium compounds. If you get too much silica in it, it vitrifies on heating.

Mr. WITHROW: The only prohibitive to the use of barium salts is the freight, is that right?

Prof. YOUNG: That would be the main difficulty, and the replacement of course would amount to something, but we have reckoned all those things pretty liberally.

Mr. SCHMIDT: You couldn't give any rough estimate as to the cost of the plant?

Prof. YOUNG: Our technical staff is pretty well scattered. Our chief engineer is away in the East and I am afraid he is manufacturing smokeless powder and some of the rest of the staff being

away, I was unable to get at the estimates and the figures. I think a ten-ton plant was within $6000 or $7000. There is no expensive construction involved.

Mr. SCHMIDT: What do you take as a basis there?

Prof. YOUNG: Ten tons of sulphur.

Mr. SCHMIDT: Ten tons in twenty-four hours?

Prof. YOUNG: In twenty-four hours, yes.

MANUFACTURE OF CREAM TARTAR

By OTTO BEST, Chem. Eng.

Read at the San Francisco Meeting, August 26, 1915

The history and development of the manufacture of cream tartar, and its allied products, tartaric acid (Rochelle salt) in this country is a phenomenal one. Its rise began with the use of cream tartar as a constituent for baking powder, for which by far most of the cream tartar is being used.

From a small industry thirty to thirty-five years ago, it has developed in this country to a production of about 1½ million to 2 million pounds per month.

It is a general belief, that a goodly portion of this product derives its raw material from California, the more so as California produces, on an average, 35 to 50 million gallons of wine annually.

However, as a matter of fact, California furnishes only a very small portion of the total used, about 400,000 to 500,000 pounds purity on raw material per year, which is not even one-half the monthly consumption of this country. The rest of the raw materials come mainly from France and Italy, very little from other countries.

Recovery of Raw Material in California. A good many efforts have been made in California to recover more tartrate raw materials. The high grade goods, argols, are saved completely. The lees, however, are not fully recovered. Most of the large wineries have recovery plants for this product, in which the main stress is laid on the recovery of the alcohol in the lees, the latter being distilled off as brandy.

The lee recovery in this case is, therefore, only incidental and not the main purpose. This is partially due to the low value of the product in comparison to the wine and brandy and partially on account of the high labor and dirty work in connection with this work. At any rate, the recovery of lees in California is anything but complete.

Extraction of Pomace. A number of years ago there were several plants in California that aimed at recovery of tartrates from pomace, the residue left after the pressing of the grapes.

These plants contributed for a number of years towards the production of tartrate raw materials. They disappeared, however, entirely; mainly on account of changed conditions in the industry.

There is no doubt in my mind that with the application of modern means, a good deal more tartrate could be recovered in California. The rapid strides of the temperance movement, and adverse legislation, no doubt has a depressing effect on the industry and greatly stifled the enterprise in this direction.

Raw Material. The raw material is partly in the form of lees, a product averaging about 35 per cent cream tartar, with varying amounts of calcium tartrate, say 2 to 5 per cent, which is deposited by the first fermentation. It consists of about two-thirds dead yeast, with sulphur, wood chips, etc., and one-third tartrates. This product is, however, mainly used in Europe for the manufacture of tartaric acid.

Argols and Lees. The raw material in this country for cream tartar is mainly argols, the secondary deposit in the wine barrels, after the fermented wine has been drawn off from the settled lees. This product averages about 70 per cent in cream tartrate.

Where gypsum is being used for the removal of some tartrates from wine, much more calcium tartrate is present. Such argols, very high in calcium tartrate, are used for the manufacture of tartaric acid.

The refineries of cream tartar are always connected with the manufacture of tartaric acid, as calcium tartrate and impure mother liquors of cream tartar have to be converted into tartaric acid. At least, there is no technical method worked out on an economic basis which would permit reconversion of those impure products into cream tartar.

As the demand for tartaric acid is comparatively small, its manufacture is more or less considered a necessary evil, and its production reduced to a minimum.

Process of Refining. There have been a number of processes employed in refining cream tartar.

Neutral Process. One of the earliest in the United States, at least, which appeared, but as early disappeared, was the so-called "neutral process." It aimed at neutralization of cream tartar by alkali, and then precipitating again by acid according to the following equations:

$$2KHT+Na_2CO_3=2KNaT+CO_2+H_2O$$

The KNaT, which is readily soluble, was separated from the pulp by filtration, and the solution precipitated as follows:

$$2\text{KNaT}+\text{H}_2\text{SO}_4=2KHT+\text{Na}_2\text{SO}_4$$

About the practical details I know little. No doubt the process failed on account of the costly chemicals used, and technical difficulties.

Settling Process. The so-called *settling* process was successfully used for a number of years, and though rather crude, has decided advantage over the "neutral process" on account of its simplicity and cheapness of operation.

It was used in two modifications, which modifications refer to the working up of the residues in tartaric acid, after extraction of most of the cream tartar.

The crude material was first ground, and charged into a large wooden cooking tank, with a perforated copper basket about 30 inches in diameter, reaching down to the bottom. The heating of the mother liquor to boil was carried out through long copper coils, while the basket was charged with live steam to keep the crude material in suspension.

It was the opinion of the early cream tartar manufacturer that this stirring had to be very violent to get all cream tartar in solution. The basket has to "dance," as the official expression was. The wood chips and undissolved cream tartar passed through the holes of the basket and settled outside the basket.

After full charge was made with a solution of from 3 to 3½ per cent, china clay was added, in order to make the suspended matter settle faster and more completely. The more china clay, the better, was another axiom of the refiner of the old day.

After settling, the fairly clean solution was drawn off into wooden, or, later on, copper crystallizers.

The aim was to get large crystals, in order to be able to remove the mechanical impurities by a washing process, and these large crystals were obtainable only by a low saturation. While full saturation of cream tartar in pure solution is 6.9 g. in 100 c.c., at 100° C., the real strength was rarely over 3.5 g. per 100 c.c.

After cooling, the cold mother liquor was pumped back again, to be recharged, and this process carried on so often, until mother liquor was too impure, and was then sent to the tartaric acid department to be worked into tartaric acid.

Washing of First (Brown) Crystals. The large, brown, cream tartar crystals, with much mechanical impurities, were crushed; that is, the aggregates broken up into large individual crystals, and these stirred up by mechanical devices.

One of these devices was a revolving drum, the so-called *rumbler*. The heavy crystals stayed on the bottom, while the lighter impurities would stay in suspension and could be drawn off from the crystals. The muddy mother liquor was used for tartaric acid manufacture. The crystals, if needed, were washed a second and a third time with mother liquor, until pure.

Acid Treatment of First Crystals. The crystals, thus obtained, contained on an average 90 to 92 per cent cream tartar. The rest was mostly calcium tartrate, a little coloring matter, traces of iron, gypsum at times, etc.

The calcium tartrate cannot be removed by recrystallization, as it is freely soluble in a hot solution of cream tartar, from which it crystallizes or deposits, as cream tartar crystallizes on cooling. It is, therefore, removed by acid. To this interesting reaction I shall come back later on.

This washing with acid was usually combined with the removal of the mechanical impurities, as described before.

After the removal of excess acid by water, the crystals tested 98 to 99 per cent in cream tartar, though the earlier *finished* product averaged only 95 per cent in cream tartar.

Removal of Calcium Tartrate by Cooking under Pressure. I wish to mention here a process which, for some time, was considered the only commercial process of removing calcium tartrate, and thus getting high grade cream tartar.

It consisted in dissolving the crystals, containing calcium tartrate, under about 100 pounds pressure. Under this pressure calcium tartrate, with 4 molecules of crystallization water changes to the anhydrous compound, which is almost insoluble, more so in pure than in impure solution. Through filtration and crystallization a high grade cream tartar could be obtained. This process has been entirely abandoned.

Recrystallization. The 98 to 99 per cent product obtained was dissolved again, decolorized with lime-free bone black (bone black treated with hydrochloric acid), china clay added to settle bone black, and the settled solution crystallized, in copper crystallizers of considerable size.

The crystals obtained from this solution were washed, dried, and ready for shipment.

The heavier mud from first (brown) cooking tank was charged and leached a second time, while the lighter mud was used as raw material for the manufacture of tartaric acid.

Acid Treatment of Mud. In some factories this mud was treated with sufficient sulphuric acid to decompose all tartrates, bring them in solution, and filter and wash the mud in filter presses.

The clear solution was then neutralized with lime, or carbonate of lime, to precipitate the tartrates as calcium tartrate, an insoluble compound, and remove the potash and other impurities by washing.

Direct Neutralization of Mud. In other factories the neutralization was carried out without removing the mud. In this case the reaction takes place in two phases:

$$2KHT+Ca(OH)_2=CaT+K_2T+H_2O$$

$$K_2T+CaSO_4=CaT+K_2SO_4$$

If the precipitation is carried out right, the calcium tartrate is granular and heavy, and settles quickly, while the suspended matter settles very slowly. If wash water is drawn off before mud has a chance to settle, soluble and insoluble impurities are removed at the same time.

The process is very simple and avoids the cost of acid and the costly filtration. Yield is also satisfactory, so that the crude settling process has the preference over the acid filtration process.

However the calcium tartrate is obtained, after complete removal of all impurities, it is decomposed by sulphuric acid into gypsum and tartaric acid, the latter worked up as further on explained.

I wish still to state that this settling process was, for a number of years, practically the only process carried out successfully on a large scale.

High-pressure Process of Cream Tartar Extraction. This process was the first attempt of getting the raw material in a filterable state, in order to remove the impurities right from the start, instead of carrying the mechanical impurities all through the process.

There is no doubt that the removal of the impurities from the start is in *principle* sound, though in practice not always possible,

without too much sacrifice. Let us see how this process attempted the solution of the problem:

Argols or lees were ground and cooked under about 100 pounds pressure for about two hours. Through this cooking, all albumin, and other constituents, detrimental to filtration, were destroyed. At any rate, the solution, after this treatment, was filterable.

The clear solution, after filtration, was run into crystallizers and crystallized and otherwise treated as described, with this difference, that mechanical impurities were removed by filtration and need not be removed by a "rumbler."

This process was mainly used for low grade goods, lees. From a technical and mechanical standpoint it works well. However, the loss on raw material is very large, particularly in presence of calcium tartrate.

Systematic investigations have shown that the loss on cream tartar was in direct proportion to the amount of calcium tartrate present under otherwise the same conditions. The latter seems to decompose more readily than cream tartar. The lime forms calcium tartrate again from cream tartar, which again is decomposed, etc.

A further drawback of this process is, that the mother liquors become very soon discolored and syrupy, and have to be discarded.

Last, but not least: A pressure process, especially with an acid product, is never a desirable process technically. For these and other reasons it is to-day practically abandoned. It is interesting from a historical standpoint, mainly, because it introduced filtration, and with it modern methods in the manufacture of cream tartar.

Roasting Process of Extracting Cream Tartar. We now come to the latest process, the so-called "Roasting Process."

Argols or lees are roasted at a temperature above the decomposition point of albumin, organic coloring matter, etc., but below the decomposition point of cream tartar and calcium tartrate. This temperature is around 150° C.

The effect of this roasting is marvelous! While argols and lees, when extracted without roasting, are practically unfilterable, just a few dark-colored drops passing through the filter cloudy, after roasting the solution passes the filter almost like water, the filtered solution is absolutely clear, and of light straw yellow color.

The roasting is, therefore, not only for the purpose of an in-

creased filtration, but is a great purifying process as well. The mother liquors from the roasted goods can be used over again much longer than from unroasted goods.

Difference of Roasting and High-pressure Process. You will note the big difference between the two processes which aimed at filtering: The first process, cooking under pressure, increases the coloring and extract matter, going into the mother liquors, and causes big losses on tartrates, besides larger technical difficulties.

The second process, dry roasting, improves the mother liquors by decreasing extract and coloring matter, is carried out *without any loss* on tartrates (I refer here to losses due to this roasting), as experiments on a small and large scale, and operations on a technical scale for years have conclusively proven. It is, furthermore, simple and efficient.

After roasting, the raw material is ground coarsely, and extracted, in wooden vessels with agitators. Boiling is avoided. The charge is now filtered through bronze filter presses into copper crystallizers, and allowed to crystallize for four or five days. The filtration is very rapid.

With a pressure not to exceed 50 to 60 pounds, 24,000 gallons could easily be filtered within about three hours without cleaning a filter-press. Whoever has tried to filter cream tartar will appreciate the technical success of this process.

The amount of filter cloth used was very low. With a monthly production of about 150,000 pounds cream tartar, the bill for filter cloth for this department was below $100.

As the labor and other items in connection with the roasting process and filtration are also low, the yield on cream tartar much higher than with the other processes, the roasting process must be considered the only rational and modern process.

Complete Extraction of Mud without Acid. The leached-out mud is extracted a second and a third time with cream tartar mother liquor in a systematic way, and is then practically free from tartrates. It is not necessary to give this residual mud an acid treatment, or send it to the acid department. It is sufficiently low in tartrates to be discharged. It still contains some phosphates, nitrogen, potash, and can, therefore, be dried and used as a filler for fertilizer.

Another great advantage of this process is, that the saturation of the solution can be much higher than with the settling process.

The saturation can be brought up to 6 per cent (with the settling process about 3½ per cent), as we need not to settle, nor depend on large crystals, as the cream tartar crystals are free from mechanical impurities. This naturally cheapens installation and manufacture.

First (or Brown) Crystals from Roasting Process. The brown crystals test about 90 to 92 per cent in cream tartar. The rest is calcium tartrate, as mentioned in the description of the previous process. The calcium tartrate crystals are usually yellow, and adhere to the edges and corners of the cream tartar crystals, as they crystallize out *after* the cream tartar is practically crystallized out.

They can clearly be distinguished from one another as the cream tartar crystals have sharp edges and corners and are transparent, while the calcium tartrate crystals look amorphous, are not transparent, and are usually uniformly colored through a trace of iron. If free of iron, they are white, but not transparent.

Removal of Calcium Tartrate from Red Crystals. On account of this property, that the calcium tartrate sticks to the surface of the cream tartar crystals, (do not permeate the cream tartar crystals throughout) they can be dissolved in acid, without fine grinding of cream tartar. The cream tartar crystals are merely crushed into individual crystals, and then treated with acid. These reactions in this connection are very interesting, as one (the first one) is reversible. Here are the reactions:

$$KHT + HCl \rightleftarrows KCl + H_2T$$

$$CaT + 2HCl = CaCl_2 + H_2T$$

The first reaction is reversible, for the reason, that cream tartar is almost insoluble in KCl solution. The solubility of pure cream tartar in a 10 per cent KCl solution is 0.04 g. cream tartar in 100 cc. The stronger the KCl, the greater the tendency of forming cream tartar back again. In reacting back, free hydrochloric acid is formed, which is capable of dissolving calcium tartrate. Thus the free hydrochloric acid is neutralized and more KCl can act on H_2T and form cream tartar and HCl. The hydrochloric acid again acts on the calcium tartrate, etc., etc.

Purity of Acid-treated Cream Tartar Crystals, and Loss on Cream Tartar to Tartaric Acid. As stated, the reverse action

takes place the more, the stronger the solution. For this reason I add *strong* hydrochloric acid, 20 to 22 degrees B. to the fairly dry cream tartar, just enough to cover it. This is about equal in weight with the calcium tartrate.

Investigation showed, that in the first twenty-four hours the purity was raised usually to about 95 per cent, while the mother liquor contained about 2 parts of cream tartar to 1 part of calcium tartrate. (Figured as calcium tartrate.)

After forty-eight hours, the purity would rise to 97.5-98 per cent, while the mother liquor contained about one part of cream tartar to one part of calcium tartrate in solution.

After seventy-two hours, the purity of the cream tartar was usually 99 per cent, or above, and the mother liquor contained now about 1 part cream tartar and 2 parts calcium tartrate.

These are average figures from practice, and change according to concentration of hydrochloric acid and temperature; but mainly with the size of calcium tartrate crystals, which vary considerably.

As will be seen, time is the essential factor of this reaction. These figures were obtained, when *no* agitation or stirring was applied.

Comparative figures, under vigorous stirring for a comparatively short time, say one-half to one hour, demonstrated that the amount of cream tartar in solution, and the amount of hydrochloric acid, were both much larger in the latter than in the former case.

In a previous paragraph I mentioned, that the manufacture of tartaric acid in this country was, more or less, considered a necessary evil. Since the hydrochloric acid solution of tartrates can only be worked into tartaric acid, it is important that as little as possible of the cream tartar is dissolved by the hydrochloric acid. Long standing with hydrochloric acid dissolves comparatively little cream tartar. More cream tartar can be precipitated from this hydrochloric acid solution by partial neutralization of the excess hydrochloric acid.

The brown cream tartar crystals thus treated with hydrochloric acid are washed with water, and test now over 99 per cent in cream tartar.

Recrystallization and Decolorization. They are redissolved, decolorized with boneblack, filtered and crystallized a second time, washed, dried, and are now colorless crystals of over 99.5 per

cent in cream tartar. When the white mother liquor does not furnish pure crystals any longer, it is discharged into the red batches. A corresponding amount of red cream tartar liquor is discharged into the tartaric acid department.

Loss in Manufacture. The loss in manufacture of cream tartar is comparatively small, as all the impure products, which cause the loss, are discharged into the tartaric acid department.

This transfers the difficulties and losses merely from one department to the other.

The loss in the cream tartar manufacture is partially due to fermentation, which loss is very low, practically *nil,* with the roasting process, larger with the other processes.

Fermentation of Crude Material. The fermentation may start with the raw material, stored away, when the same had not been completely dried. In order to establish this loss, a cream tartar test (Klein test) is made from the raw material and a potash determination, and the latter figured into cream tartar. If this figure is higher than the direct determination, loss through fermentation of raw material has occurred.

Loss through Cooking. Some loss is due to cooking, possibly a little through roasting, though a direct determination never disclosed a loss in either direction.

There is no further source of loss, outside of some mechanical loss.

Manufacture of Tartaric Acid. We now come to the manufacture of tartaric acid. As indicated above, all products of cream tartar manufacture, too impure for cream tartar, are transferred to the tartaric department.

The various sources are: Impure cream tartar mother liquor, and the tartrates from the hydrochloric acid treatment. No mud need be treated in the roasting process, as the extraction in the cream tartar department is complete.

Manufacture of Calcium Tartrate. These products are transformed into calcium tartrate, an insoluble compound, which can be washed for the removal of the impurities.

If we manufacture calcium tartrate from cream tartar crude material, two steps are needed, as explained before. These products, with excess hydrochloric acid, form enough $CaCl_2$ to precipitate the neutral tartrates as calcium tartrate, without further addition of gypsum.

SOLUBILITY OF CALCIUM TARTRATE. The solubility of calcium tartrate is about one part in 6000 parts of cold water. This solubility is raised to 1 in 500 parts in *hot* water. It is well, therefore, to neutralize cold, if large losses are to be avoided.

Impurities in solution effect the solubility of calcium tartrate. $CaCl_2$ and KCl, *decrease* the solubility of calcium tartrate. All other impurities seem to *increase* the solubility of calcium tartrate. Organic substances in solution, for instance, considerably increase its solubility; so do iron and aluminum salts, phosphates, sulphates, etc. This is the main reason why the loss in manufacture is transferred from cream tartar to tartaric acid.

PROPORTION OF CREAM TARTAR TO TARTARIC ACID. Usually only about 10 per cent of the production of cream tartar is obtained for tartaric acid manufacture, and by skillful manipulation it can be kept much lower. Correspondingly, the impurities in the tartaric acid department are increased. It needs very careful operation, and full control of all operations to keep the loss down.

LOSS THROUGH PRECIPITATION AS CALCIUM TARTRATE. This precipitation entails the biggest loss of any individual step. It needs, therefore, the most attention and study. It also needs full attention, as in this step the impurities are removed, and if fully removed, will make subsequent steps easier and losses smaller.

The neutralization was carried out by some manufacturers with lime; but most manufacturers use now carbonate of lime. After neutralization, the calcium tartrate is washed by decantation, until all impurities are removed. This has to be done swiftly, as otherwise calcium tartrate will ferment and cause loss.

EVAPORATION OF TARTARIC ACID. The pure calcium tartrate is decomposed with a very small excess of H_2SO_4, evaporated at low temperature, say not to exceed 170° F., usually at first in open evaporators, then *in vacuo,* until saturated hot, and then run into crystallizers. The cooled-off mother liquor is evaporated a second, third, etc., time, as long as it still forms good crystals. Last impure liquor is reprecipitated.

All crystals are washed, dissolved, decolorized, filtered, evaporated and again crystallized, to form commercial tartaric acid.

If evaporation is carried out in open vessels, the temperature has to be controlled carefully, otherwise large losses on tartaric acid will be incurred.

META-TARTARIC ACID. Another source of loss is due to the

formation of meta-tartaric acid. This acid is formed through evaporation in open vessels, especially in presence of impurities. It is supposed to be a semi-anhydride of tartaric acid, non-crystallizable, with calcium and acid potassium salts much more soluble than the ordinary tartrates.

If present in larger quantities, tartaric acid will not crystallize, though evaporated much above the saturation point of tartaric acid.

Reprecipitating cold with lime or calcium carbonate will entail a large loss, on account of the higher solubility of the calcium meta-tartrate over the ordinary tartrate of lime. When this calcium meta-tartrate is heated to boil, it is changed back to the ordinary calcium tartrate, and after decomposition with sulphuric acid will give crystallized tartaric acid again.

In a well-regulated factory with vacuum evaporators, meta-tartaric acid will not be found.

A number of years ago I worked out an approximate determination of meta-tartaric acid. I did not follow it up, for the reason that I prevented its formation.

The brown tartaric acid, as it comes from the crystallizers, is washed, dissolved in water, decolorized, evaporated *in vacuo* to saturation hot, crystals taken out after five to six days' standing, washed, dried, screened, and are now ready for shipment.

The mother liquor is evaporated a second and third time, as long as good crystals are obtained, and the last white mother liquor returned to the first brown.

Re-precipitation of Tartaric Acid as Cream Tartar. There used to be a process of working up the last brown tartaric acid in order to recover cream tartar, and to remove the impurities at the same time. This mother liquor, which contains many impurities and free sulphuric acid, was diluted, and the free sulphuric acid neutralized by lime. The gypsum formed was filtered off, and the remaining clear solution treated with excess KCl. The reactions taking place were as follows:

$$3H_2T+3KCl=3KHT+3HCl$$

Considerable hydrochloric acid is being formed when about 5 per cent KCl is in excess.

But there are impurities present, such as Fe, Al, K, etc., which

will combine with the free acid and make precipitation more complete, while the metals stay in solution as chlorides, and are removed as such. I give the following reaction as an illustration:

$$Al_2T_3+3KCl+3HCl=3KHT+2AlCl_3$$

The two reactions are, of course, simultaneous.

This process, I believe, is abandoned, as it was too expensive on account of the costly potash salts used, and the large loss in tartrates. However, it was one practical attempt to divert tartaric acid into cream tartar, at the same time removing the impurities.

Other Processes of Tartaric Acid Manufacture. I wish to state that where Tartaric Acid is manufactured, not as a by-product of cream tartar manufacture, but as the main or only product, as in many European countries, a number of processes are known for the manufacture of tartaric acid. These processes, however, are outside the scope of this paper, as we are in the first case interested in the industries, as they were called into existence in this country through economic conditions.

Refining in One Operation, or Crystallization. In general, I want to say that some attempt has been made, both in cream tartar and tartaric acid manufacture, to refine these products in *one* crystallization, and I myself have carried out many experiments, without, however, having gone beyond the laboratory scale. Short cuts of this kind are very tempting, because of the shortening of the process and consequent smaller investment and cheaper production. Such attempts have been successful in other branchees of manufacture, like boracic acid, borax, etc. But to the best of my knowledge, no such process has successfully been carried out in the manufacture of cream tartar and tartaric acid in this country.

In France, I was informed, a process was introduced on the line of the *neutral* process, which claims pure cream tartar in one operation. How successful it is technically, I cannot tell.

To reiterate: Of all processes advocated and carried out in America, the only survivor seems to be the "roasting process," which, in some form or other, is practically carried out in every large cream tartar refinery in this country. It is rational, because it removes the impurities, and with it the trouble *from the start;* it permits the introduction of modern filtering apparatus and appliances, without being too costly, to offset these advantages. It

is a clean process from beginning to end, easily and fully controllable.

It gives high yield and rather *avoids,* than cures, trouble and disease.

These, in my mind, are the chief characteristics of a modern process, of which the "roasting process," in connection with cream tartar manufacture, is an example.

DISCUSSION

The CHAIRMAN: The paper is open for discussion or comment.

Mr. C. C. SCALIONE: You spoke of the lees and of pomace being two sources; do they ever use the scrapings off the tanks?

Dr. BEST: The lees are formed by the first fermentation. The grape juice as it comes from the wine is let into barrels and is fermented. Through the fermentation alcohol is formed in which cream of tartar is much less soluble and drops down with the yeast. The pomace, however, is a different product. It is the residue left after the wine is pressed out and it used to be leached out by cooking. They are comparatively very low in cream of tartar, only about 1 or 2 per cent, and several cookings had to be made in order to get the saturation to crystallization; lees contain about 35 per cent of cream of tartar.

Prof. WITHROW: How long has this process been in operation?

Dr. BEST: I introduced it in California about sixteen years ago.

Dr. BECKMAN: I would like to ask Dr. Best about the reaction: $K_2T+CaSO_4=CaT+K_2SO_4$, as the latter is practically insoluble. How does that take place?

Dr. BEST: K_2T is dissolved in about between 1 to 4 parts of water and mixed and stirred with excess gypsum. The reaction goes on practically quantitatively. I wish to say, however, that in the presence of concentrated solutions of potassium sulphate the reaction is reversed to some extent, and that is the cause of the loss of calcium tartrate. If calcium chloride is used the loss on tartrate is much smaller.

Dr. BECKMAN: Is that reaction carried on on a large scale?

Dr. BEST: Yes. The usual way is to wash calcium tartrate. Now sulphuric acid is added in the same tank which forms gypsum and tartaric acid. Then the whole is filtered through the filtering press. Some of the gypsum is left in the tank, and in the next

operation sufficient gypsum is there to finish the reaction, so the two reactions of neutralization with lime and of decomposition of the neutral tartrates with gypsum goes on simultaneously.

Mr. C. C. SCALIONE: You spoke of crystallizing out the cream of tartar, and having calcium tartrate, regardless of how many times you crystallize them out. Is that calcium tartrate in the same proportion every time you crystallize it out?

Dr. BEST: No; it changes to some extent. Suppose you start cooling down to about 90° F.; the purity is practically the same if you cool down to 150° F., the first cream of tartar coming out is practically pure.

Mr. C. C. SCALIONE: What I was driving at was to see if your calcium tartrate and your cream of tartar was forming a constant composition of crystal?

Dr. BEST: No.

Mr. J. WINKLER: You spoke of crystallization. In regard to the small and large crystals,—of course using a less concentrated solution, it crystallizes more slowly. Suppose you used a nearly saturated solution and allowed it to cool much more slowly, then would you not also get large crystals?

Dr. BEST: Yes; but the operation is so large that it cools by itself very slowly. If the solution is fully saturated, the crystallization starts immediately, and the dropping of the crystals will carry down more, and all the cream of tartar will be found on the bottom in immense volume instead of a comparatively small volume at the sides with less saturation. In the latter case there will be crystals like my thumb.

Mr. C. C. SCALIONE: Do you use any particular metal rods in the tanks?

Dr. BEST: No, nothing at all.

Mr. J. WINKLER: The small crystals are what we want in the soda ash proposition.

Mr. C. C. SCALIONE: In your roasting processes is there any danger of decomposing the cream of tartar?

Dr. BEST: None at all. The roasting is carried on in jacketed steel vessels that carry 100 pounds pressure, which is exactly the pressure of the boiler. If the boiler was set for 100 pounds it couldn't go beyond that pressure, therefore not beyond the temperature corresponding to that pressure, which is below the decomposition point of cream tartar.

ENGINEERING FEATURES OF WINE MAKING

By Dr. ARTHUR LACHMAN

Read at the San Francisco Meeting, Aug. 25, 1915

In confining this paper to the engineering side of wine making it will necessarily be impossible to go into the agricultural and viticultural features more than very briefly. The grapes that are used for wine making in California are available for wine making from three separate sources. We have grapes which are grown exclusively for wine making purposes; we have grapes which are obtained as a by-product, so to speak, of the raisin industry, and we have grapes which are a by-product of the table grape industry. The wine making grapes used in California are largely imported varieties which have been brought from time to time from France, Germany, Hungary and Italy, and by far the larger part of the wine crop is made from wine grapes proper. The raisin industry gives as its by-product the so called second crop of the muscat grape. These are obtained too late for natural drying in the sun and find their way into the wineries where they are used for wine or brandy making. The table grape industry also gives a by-product. The later tokay grapes and the seedless grape which are so popular for table use in the early season are used for wine making because their later varieties do not ship well.

Wine grapes in California are grown in three sections of the state. The northern section, which is from fifty to one hundred miles north of San Francisco, comprises the counties of Napa and Sonoma, and are true wine grape producing sections. The central section of California, centering around Stockton, is largely a table grape region but produces a considerable amount of wine grapes also. The southern section of the state, including both the southern central section centering in Fresno and the section centering in and around Los Angeles, produces about equal parts of true wine grapes and of raisin by-product grapes.

The tonnage of grapes which is crushed for wine making fluctuates considerably, and it is impossible to determine at the beginning of a season just how large a percentage of the by-product grapes will

be turned into the wineries. That depends upon market conditions. When raisins are high the grower will attempt to dry as much as possible of his grape crop and the winery by-product will be small. When table grapes bring a good price a relatively small amount will reach the wineries, so that the tonnage is largely a matter of speculation even up to the very last day on which grapes are crushed. While in this state we have a State Viticultural Commission, its activities are frequently interrupted for political reasons and as a result our data are not at all reliable, but it is safe to say that under normal conditions when business is good and crops are fair something like half a million tons of grapes are crushed every season.

The season itself is very short. Wine grapes are crushed in a period of from forty-five to ninety days. I have known it to be as short as thirty days and to last as long as 110 or 120 days, but sixty days is about the average crushing season. This means, of course, a very heavy overhead load on the industry. Within the period of two months enough grapes must be crushed to last until the following vintage; in other words, we have an idle season for our equipment of nearly ten months every year.

The first engineering problem in wine making is the transportation of grapes from the vineyards to the wineries. I may say in passing that the wine industry in California is practically as old as the state and dates back to the time of the first Spanish monks, who settled in the southern part of the state over a hundred years ago. The industry has changed in that the small grower, the man with twenty to one hundred acres of grapes, no longer crushes his own grapes and makes his own wine. That is the practice which is still in use in Europe; in California, however, the industry has changed so that grape growing and grape crushing have become two separate industries and the wine maker is not as a rule the wine grower. The wine maker buys his grapes. The grower disposes of his grapes for cash and then his financial troubles are over.

It is of course necessary that grapes reach the wine maker in as good a condition as possible. When the haul from the vineyard to the winery is short—and by short we mean time rather than mileage—grapes are transported in large flat tanks. These tanks are built up on ordinary flat cars with a one or two foot wooden siding and lined with a large sheet of heavy canvas. This makes a very flat canvas tub in which the grapes are merely dumped loosely and hauled to the winery. When the haul can be completed over night—in

other words, when grapes that are dumped into these flat cars to-day can be received at the winery to-morrow morning—the tank car offers an excellent transportation medium and gives little or no trouble.

When, however, grapes must be hauled a day and a half or two days the weight of the two or three foot load crushes the grapes in the bottom of the car, and as a result a partly fermenting, partly liquid, mushy grape mass is produced which is not only unappetizing but which gives a poor wine. Fermentation has begun, bacterial action of an undesirable character has started in so that the transportation of grapes in this manner is unsatisfactory. The bacterial infection makes it necessary to pasteurize or sterilize the entire mass before beginning wine-making operations. For this purpose the contents of the car after crushing are pasteurized at a rather high temperature and then cooled to permit of ordinary fermentation. It is doubtful whether the cost of the treatment will not exceed the saving in transportation charges. Where grapes travel a long distance it is better to ship them to the winery in ordinary wooden boxes which hold approximately fifty pounds of grapes.

After grapes are received at the winery a chain conveyor is used to transport them to the crushers. These conveyors are frequently two or three hundred feet long. In some wineries a screw conveyor is used but the ordinary draper seems to be the most satisfactory. The crushing is carried on in machines which have been developed from types originally brought out in Europe. A pair of corrugated iron rolls receives the grapes and crushes them to a fairly fine pulp. This material then drops down into a strainer in which there is a rapidly revolving set of narrow blades. These blades tear out the stems very completely from the mass of pulp, throwing them out to one side. This stemming process is desirable for two reasons. In the first place, stems have a tendency to clog the pipes and flumes that are used for conveying crushed grapes and, in the second place, the stems impart an undesirable taste to the wine so that for both of these excellent reasons it is desirable to remove them as early as possible.

The crushed material after the stems have been removed is usually delivered into the fermenting tanks by a slow-moving plunger pump which has been developed for this special purpose. The pump works at from ten to fifteen strokes per minute and pumps the thick gluey material through four-inch pipes to the fermenting tanks. As a rule this offers no serious difficulty, but oc-

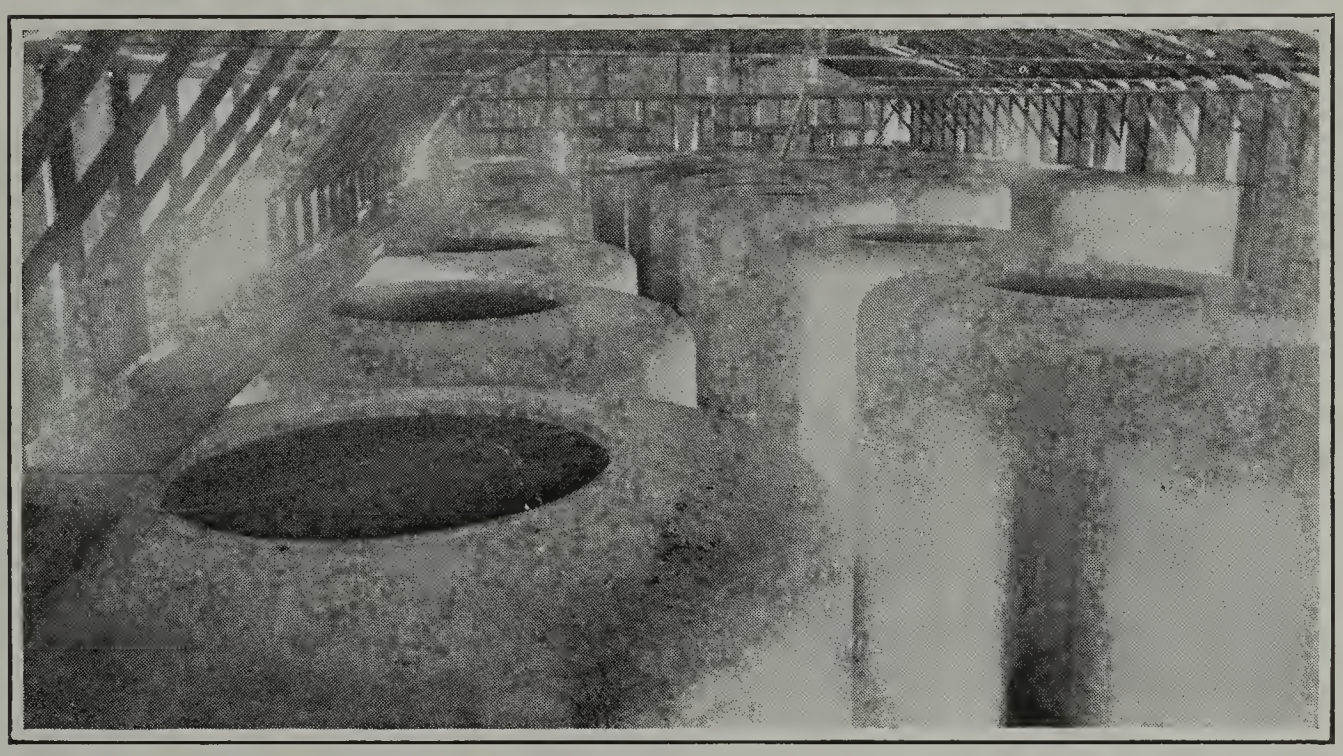
casionally a pipe will clog. In large plants as a rule two crushers are employed, one for red grapes and one for white, so as to save time; in fact, time saving during the season is the essential controlling feature of engineering in wine making.

The raw material having been pumped into the tanks, it is allowed to undergo a natural fermentation. In some few wineries pure yeast cultures are used, but their use implies a prior sterilization of the must which is costly and above all time consuming. As a rule the fermentation offers no serious difficulties under California conditions. The control of fermentation involves practically only a control of temperature. As grape juice ferments a rather rapid rise in temperature accompanies it. For each percentage of sugar fermented approximately two degrees Fahr. increase in temperature will be noted provided there is no loss of heat through radiation and evaporation. This would give an ultimate temperature far too high for fermentation purposes. The proper temperature for fermentation is between 85 and 95 degrees Fahr. and a temperature of over a hundred degrees Fahr. will inhibit or slow down the action of the yeast and lead to a condition known as "stuck wine." These stuck wines contain a residual amount of sugar which is undesirable. At high temperatures bacterial action, notably souring, starts in rapidly and wines in which the fermentation temperature has been too high have an unpalatable taste and are generally inferior products.

The control of temperature is brought about in several ways. The commonest is to cool the fermenting wine with water in closed pipes, the pipes either being submerged in the tank itself or more commonly the wine is pumped through pipes over which water is allowed to flow. In some plants refrigerating machines are used for this purpose. They are too expensive, as a large volume of cold water will give the same result and is much cheaper. Occasionally in the smaller plants temperature is controlled by simply taking the hot juice and mixing it with cold, fresh juice, and a large amount of heat disappears by radiation through the walls of the tanks. In my own winery the problem has been solved, accidentally to be sure, but very happily, by the use of cement fermenting tanks. We use cement tanks with very thin walls, only two inches thick. These tanks radiate heat so rapidly that they automatically control fermentation temperatures, and instead of getting a rise of two degrees Fahr. for each percentage of sugar we get a rise of about half a

degree for each percentage of sugar, and our maximum temperature never exceeds a safe limit.

The fermentation is complete when the sugar in the wine has disappeared. This is controlled by an ordinary hydrometer. Fresh grape must in California will show a density of from twenty to twenty-eight degrees Balling, which approximates very closely the percentage of sugar actually present; when the fermentation is completed the wine will usually show a density below zero Balling due to the alcohol which has been produced and which is lighter than water. After fermentation has been completed the fermented material is very difficult to handle. If a fine strainer is used to



Cement Fermenting Tanks.

separate the juice from the pomace it plugs up, and if a coarse strainer the material goes through and clogs pipes and valves and everything else. We use a wooden strainer with apertures about a quarter of an inch between slats, but there is a constant struggle between the wine maker and the strainer from the beginning of the vintage to the very end.

During the fermentation the wine maker must decide whether or not his grapes are to be made into sweet wines, or into dry wines. Sweet wines differ from dry wines in that they contain a certain percentage of the original sugar of the grapes, which percentage of sugar is preserved by the addition of brandy. This process is known as "fortification" and is conducted under the supervision of the U. S. Internal Revenue Department, a U. S. gauger

being present during the operation. The fortification is carried out very simply. The amount of brandy necessary is calculated from tables which are provided, and this amount is merely pumped into the wine. As a rule sweet wines are so fortified as to contain approximately 20 per cent of alcohol. This effectually stops all further fermentation. Dry wines, on the other hand, contain practically no sugar. In Europe where wine making is carried out under less favorable climatic conditions than in California, fermentation usually stops when the wine still contains from one to four per cent of sugar. During the following spring and summer when the wine becomes warm again a secondary fermentation starts in, which must be complete before the wine is marketable. In California we are fortunate in that this secondary fermentation does not occur. We get a complete fermentation in the early stages of the operation.

After the juice is racked off we have the problem of disposing of the pomace. It is either pressed in a basket, made of wood, with a cylinder which is operated by a hydraulic ram or a continuous press is used which consists of a screw conveyor pressing the mass through a narrowed orifice and giving sufficient pressure to extract the greater part of the juice still remaining in the pomace. After pressing, the pomace is washed with water to recover its alcoholic content, which is rather high, and then pressed again and discarded. Its by-product value is not large and practically nothing is done with it at present. Another method of disposing of the pomace is to distill it in its natural state either before or after pressing, producing a highly flavored brandy which is very much desired by the Italian consumers in this country. This brandy is known as Grappa. It corresponds to the European type of brandy known as Trester brandy. This distillation is conducted in a large chamber or pot still. My own chamber still has a capacity of something like eight tons of pomace. It operates discontinuously and is heated by a current of live steam. The product of a pot still is a weak brandy with about 30 or 35 per cent of alcohol which is too weak for commercial purposes. This product is known as "singlings" and is redistilled or refractioned until it has the necessary alcoholic strength. This process is technically known as "doubling."

The wash water or "wash" which is obtained from pomace is distilled in ordinary continuous column stills for the production of brandy. These stills offer nothing novel in their construction, the ordinary type of continuous column still being used, with verti-

cal columns and about 15 to 25 chambers. Repeated refractionation occurs in the chambers and the product comes over at almost any desired strength. The usual strength at which brandy is distilled in California is about 75 per cent, and after distillation it is reduced with water to the commercial strength of 50 to 55 per cent. It is not desired in making brandy to get as high a rectification as in the manufacture of alcohol. The flavor of the brandy is due to traces of various ingredients, the nature of which is practically unknown. These are retained if the brandy is not distilled at too high a percentage of alcohol.

The next stage in wine making is the process of maturing. This is usually conducted in separate establishments. The wine industry has followed in the steps of the sugar industry in this respect in that the wine is not matured as a rule in the same establishments in which it is crushed and fermented. The reasons for this are largely commercial. There is no necessity for the separation any more than there is in the sugar industry except that it has developed in this manner and still continues.

There are two problems in the maturing of wines. The first of these is to get the wine clear, and by clearness is meant crystal sparkling brilliancy. The consumer of wines is very particular as to the physical characteristics of his beverage. It must have no trace of sediment of any sort and a very small percentage, a few thousandths of one per cent of turbidity in a wine will make it appear murky and unappetizing. The filtration is carried on with filters of various types and degrees of efficiency. Primitive wineries used ordinary bags of the sugar loaf pattern made of a thick felt through which the wine was allowed to trickle; while other wineries use the old-style chamber presses with a cotton or woolen cloth as the filtering medium. The filtration under these circumstances is conducted under moderate pressure.

The filters enjoying the largest use, however, employ finely divided materials as an aid in filtration. These materials are either paper or asbestos pulp. The paper pulp filter which enjoys the greatest popularity in this country is the Kiefer filter, which is manufactured in Cincinnati. The paper pulp is beaten up into a thick mass and then pressed in a frame which gives a circular cake. This circular cake is placed in a cylindrical machine and highly compressed at the center, thus giving an impervious central tube through which the clear wine may pass. The muddy wine is allowed to

come up outside of the cakes and with pressure of perhaps 20 or 30 pounds to the square inch is forced through the pulp and discharged through the central channel. Asbestos filters employ asbestos pulp, which is beaten up with the wine and allowed to deposit upon a fine screen very similar to the screen used in paper making. A very fine sheet is deposited on these screens and filtration is then continued by gravity. The asbestos screens are very efficient. They practically give a sterilized effluent. The pores of the pulp are so fine that the ordinary type of wine bacteria are largely retained.

However, when wine is newly made, and for the first two or three months of its history, filtration is a very annoying operation. The finely divided albumenoids and other solids contained in the wine clog up practically every filtering medium in a very short time, so that for practical purposes better results are obtained by the ordinary old-fashioned method of decantation. The wine is allowed to rest in closed tanks for a few weeks and then is drawn off again. Then it is allowed to rest and is drawn off again. This operation is repeated three to five times until finally a fairly clear liquid is obtained, which is then easily filtered through the filtering appliances just described.

Another difficulty is that after wine has been filtered it does not remain clear, due partly to oxidation and partly to some of the colloidal ingredients becoming insoluble. Wine which has been filtered clear becomes turbid in a very short while, so that repeated filtration is necessary before the wine is thoroughly matured. Another factor which produces turbidity is bacterial action. There are a great many bacteria which act upon wine and render it unfit for use. These bacteria are of various types. Most of them are connected with the formation of acetic acid, rendering the wine unpalatable.

The bacteria are very easily checked by heating or pasteurizing. For this purpose a pasteurizing machine is used which is essentially a small heater connected with tubes through which the wine passes on its way to the heater and over which it passes on its way from the heater, thus effecting an exchange of heat between the hot wine going out and the cold wine coming in. They are very economical to operate and work on the counter-current principle. There is no mechanical or chemical difficulty in connection with these pasteurizers. The best pasteurizing temperature for wines is approximately 175 degrees Fahr. or 80 degrees C.

A further problem in the maturing of wines other than the

filtration is the blending and the aging. Blending is the art of making wines commercially uniform. Practically all California wines are blended to obtain this uniformity. There is considerable variation in the quality of wines produced in different vineyards from season to season. The aging of wines is the acquisition of those delicate and intangible flavors which we group under the name "bouquet." The mere passing of time will not develop bouquet in a wine; on the other hand, time is not always necessary to develop bouquet. There is a great difference between wines in regard to the period necessary for the development of their natural bouquet. Some wines will develop their bouquet in three or four months, others will not do so for three or four years. Other wines again when kept three or four or five years merely spoil without developing bouquet.

There are a number of artificial methods for aging wines. This is notably the case in regard to the type of wine known as sherry. Sherry is a wine of Spanish origin where it is matured by the simple but effective process of rolling the barrels containing the wine into the sun every day. This is carried on for six or eight or ten months or more, and the heat of the sun which probably produces a temperature of 120° Fahr. inside the barrels, is sufficient to produce the characteristic sherry bouquet or flavor. In California, due to labor being expensive, we have changed this Spanish method and simplified and cheapened it very materially. The wine is placed in large tanks and heated artificially either with steam pipes inside of the wine or by heating the room in which the tanks are contained. The wine is kept at a temperature of about 140 degrees for a period of four or five months and acquires the same characteristic bouquet that is obtained in Spain. On the other hand, even the California process can be hastened. I have developed a process which produces the same effect in something like twenty-four hours. We pump the raw wine in at one end and take sherry out at the other. It is merely a question of controlling the chemical and above all the oxidation conditions which are necessary to develop the proper bouquet. A further saving that my sherry process accomplishes is in cutting down the evaporation loss. When wine has to steam in wooden tanks for from four to six months there is very considerable shrinkage, approximately ten to fifteen per cent. The new method being practically instantaneous and conducted in metal vessels there is no loss at all.

Then there are other aging processes which can be adopted for wines. For example, white wines of the Rhine and Moselle types are usually desired to be proof against chilling. These white wines are served cold and before they reach the table or the restaurant table they are stuck in an ice cooler. As the wine must remain clear under this rather severe treatment we have adopted the plan of chilling the wine first. We cool the wine with a refrigerating machine a few degrees lower than freezing temperature and then filter it. Then we know when it is subsequently chilled at a temperature several degrees higher it will not deposit any more.

Various methods of this sort have been developed for the purpose of adapting wines to the use to which they are to be put later on. However, all of the artificial aging has its limitations. These are due to the fact that grapes ripen at best only during two months in the year. Now the crushing season coincides with the heavy market season. In other words, we are busy selling wine at the time we are busy making it. As it is impossible to deliver wine fresh from the press we must deliver now the wine we made last year. Therefore, it becomes necessary to hold the wine in our cellars on the average at least a year before we are able to market it. This being the case artificial aging has no particular advantages as you have all the time you need anyhow. It is only a matter of detail whether you prefer to use artificial methods or not. It would be possible to mature, say, the 1915 crop some time in the spring of 1916, but by that time the buying season is over and the wine will not move into its markets again until the fall of 1916 and the interval in between is wasted if you try to hasten the aging appreciably.

In conclusion, then, we see that the engineering features of wine making are not especially complicated. A great variety of equipment is called for and it remains idle from eight to ten months in the year. The wine maker is a very busy person for two or three months and the rest of the time he is out of work and at his leisure. He must be an engineer, but above all he needs to be a competent manager and executive, and that in itself merely restates the fact that he must be an engineer, because engineering is nothing more than applying common sense.

DISCUSSION

The CHAIRMAN: We are under obligation to Dr. Lachman for his very interesting paper. The subject is now open to question and discussion.

Mr. BARUCH: Dr. Lachman spoke of building cement vats with walls only a few inches in thickness. May I ask how those were constructed and how you make them waterproof?

Dr. LACHMAN: The chief element in the construction of those tanks was twenty dollar gold pieces. They were very expensive. They were made by building a cage of iron bars spaced approximately one foot apart, the space being filled with iron cloth, and then the cement was merely plastered on with a trowel, first inside and then out; then another layer inside and then another outside. I think perhaps two or three coats were applied on each side.

Mr. BARUCH: How thick?

Dr. LACHMAN: From a quarter to a half inch every time.

Mr. BARUCH: Did you ever try the cement gun?

Dr. LACHMAN: If I ever built any again I would try it. The method I used was all right except that it was too expensive.

Mr. BARUCH: How large were those tanks?

Dr. LACHMAN: About ten feet in diameter and about ten feet high. They were very satisfactory but very costly.

Mr. BARUCH: Are they waterproof?

Dr. LACHMAN: Absolutely.

Mr. BARUCH: What mixture of sand and cement?

Dr. LACHMAN: I think something like three and one.

Mr. BARUCH: Are they the same thickness at the bottom and the top?

Dr. LACHMAN: Yes, uniform, but more reenforcement at the bottom.

Mr. BARUCH: No steel hoops or anything on the outside?

Dr. LACHMAN: Oh, yes, hoops, lots of hoops. The hoops are inside; all the iron is inside.

Mr. BARUCH: But covered with cement?

Dr. LACHMAN: The hoops are made of half inch plain bars; they are not even corrugated.

Mr. ALEXANDER: You build up a frame and cover it with cement?

Dr. LACHMAN: Just like a bird cage.

Mr. ALEXANDER: The hoops are troweled down smooth?

Dr. LACHMAN: The hoops are troweled down smooth afterwards.

Prof. WITHROW: How long have they been in service, doctor?

Dr. LACHMAN: Three years. Wine has a tendency to make cement waterproof. That reminds me that I once built cement tanks of a larger size, six-inch walls, but poured in forms, and those tanks leaked very heavily when filled with water. I plugged them by filling them with lime water and allowing the natural carbonation to swell them up, and it worked very well.

Mr. CULVER: I would like to ask whether, in making white wine, blue grapes are used?

Dr. LACHMAN: As a rule a special white wine variety of grapes of imported cuttings is used. The grapes are the Burger, the Reisling, the Golden Chasselas, and then the French varieties of Sauvignon and Columbar. Those are the commonest in California.

Mr. CULVER: Are those blue grapes?

Dr. LACHMAN: They are green or yellow.

Mr. CULVER: You use blue grapes for claret?

Dr. LACHMAN: Blue grapes for claret. The blue grapes will yield white wine if they are crushed and drawn off immediately. The coloring matter is contained in the skins, so that a white wine can be made from a black grape if necessary, and that frequently is done. The reason it is not done now is that commercially the demand for red wine is very much greater than for white wine.

Mr. CULVER: I would also like to ask something in regard to presses. Have you considered the new press which the Henry R. Worthington Branch of the International Pump Works is putting out?

Dr. LACHMAN: I have a quotation on one of those presses. I should say for wine making, making white wines, which are frequently fermented off the skins, they would be very satisfactory, but they are very slow in operation and I believe altogether too costly for wine making.

Mr. CULVER: I understand they are used in the grape juice industry.

Dr. LACHMAN: Yes, they can be used there to better advantage.

THE TREATMENT OF SEWAGE BY AERATION IN THE PRESENCE OF ACTIVATED SLUDGE

By EDWARD BARTOW

Read at San Francisco Meeting, Palo Alto, August 27, 1915

Sewage treatment by aeration in the presence of sludge is the latest development in sewage disposal. Air has always played an important role in sewage disposal. The earliest application of air was the exposure of sewage on the ground or in shallow pools. The disposal of sewage by irrigation is, therefore, an aeration process. No more sewage can be added to land than can be thoroughly oxidized. The disposal of sewage by dilution in streams also depends on the amount of air present. The amount of sewage which can be purified by a stream is limited by the amount of dissolved oxygen present. The efficiency of the stream depends upon the amount of water or the amount of oxygen in solution or the possibility of reaeration.

Intermittent sand filtration, where sewage is added intermittently to sand beds, is an aeration process, for between the periods of flooding with sewage, air is allowed to enter the pores of the sand. The action of contact beds is of a similar nature. Coarser material is used and between the periods of flooding air enters the interstices and is the purifying agent. Sprinkling filters, the most practical process up to the time of the suggestion of activated sludge, depend upon aeration accomplished by spreading the sewage in a finely divided state into the air.

Preliminary to these aeration processes preparatory treatment is necessary. Preparatory treatment consists in using screens, grit chambers, settling tanks, digestion tanks or chemical precipitation. The preparatory treatment varies according to conditions. For example, three cities visited in Europe use different degrees of preparatory treatment prior to disposal by dilution. Munich uses no screening whatever, the water in the Yser being of sufficient quantity and sufficiently aerated to dispose of the sewage. Hamburg can dispose of its sewage in the lower Elbe using only coarse

screening, but Dresden on the upper Elbe must pass its sewage through fine screens before emptying it into the river.

Grit chambers and settling tanks remove suspended matter. The amount of purification is comparable with the amount of purification by screening.

Digestion tanks accomplish the partial destruction of the suspended solids and soluble organic matter by anaerobic bacteria.

The addition of chemicals assists sedimentation and retards digestion, giving an increased amount of sludge, but a much improved effluent. Neither the screening nor the sedimentation nor the digestion nor the chemical precipitation produce complete purification. Aeration processes must complete the purification.

The latest process, the aeration of sewage in the presence of sludge, has had a gradual development. Numerous experiments of blowing air into sewage have been made both in America and in Europe. Until recently none of the experiments were at all promising and the conclusion was that such means of purification was not practical. In this country, the first promising method was that used by Black and Phelps[1] in New York. They blew air through the sewage as it passed over a series of inclined wooden gratings. This sewage was in contact with the air for varying periods up to twenty-four hours. The results were promising enough to cause Black and Phelps to recommend the construction of a larger plant for Greater New York. That plant has not been constructed and the experimental tank has been adapted to experiments with activated sludge.

The next experiments are those reported by Clark, Gage and Adams[2] at the Massachusetts State Board of Health Experiment Station in Lawrence. Air blown through sewage reduced the organic constituents. The seeding of the sewage with green growths accelerated the action. Their best results were obtained when the tank contained slabs of slate covered with a brown growth of sewage matters. This treatment produced an effluent which could be filtered at several times the normal rate. It, however, simply prepared the sewage for addition to sand beds, and was not considered a final process.

Gilbert J. Fowler of the University of Manchester was in

[1] "Report Concerning Location of Sewer Outlets and the Discharge of Sewage into New York Harbor" 1911, 64–78.

[2] Annual Report Mass. State Bd. of Health, **45**, 288–304 (1913).

this country in November, 1912, in connection with the disposal of the sewage of Greater New York and visited the Massachusetts Experiment Station. Fowler and Mumford carried on experiments with a specific bacillus which they named M-7 which was collected from the waste water from a colliery. This bacillus with aeration has the power of separating iron as ferric hydroxide from iron bearing sewages, carrying down with it the suspended matter, and furnishing a non-putrescible effluent. Fowler suggested to Ardern and Lockett, who were in charge of the Manchester Sewage Disposal Works, that they try experiments in aerating sewage on lines somewhat similar to what he saw in Massachusetts. As a result the activated sludge process is being developed.

The first description of it was given by Ardern and Lockett,[1] April 3, 1914, at a meeting of the Manchester Section of the Society of Chemical Industry. In their first experiments Ardern and Lockett used five-pint bottles and drew the air through the sewage by means of an ordinary filter pump. Air was drawn through the sewage until it was completely nitrified, requiring about five weeks. The supernatant liquid was drawn off and additional sewage added. This method of treatment was repeated a number of times with the retention each time of the deposited solids. As the amount of deposited matter increased the time required for each succeeding oxidation gradually diminished. Finally a well oxidized effluent, equal to that from efficient bacterial filters, was obtained in from six to nine hours.

In their second series of experiments, reported to the Manchester Section of the Society of Chemical Industry[2] Nov. 6, 1914, they used barrels of fifty gallons capacity and added the air through porous tile. They had tried treatment with a continuous flow of sewage without conclusive results. In later experiments they used tanks of 20,000 gallons capacity. Their results were very satisfactory and led to additional work in England, especially at Salford where Duckworth[3] and Melling[4] adapted scrubbing filters to the use of the activated sludge process with great success. In August, 1914, I had the privilege of meeting Professor Fowler and of seeing the work which had been done under his direction. On returning to

[1] *J. Soc. Chem. Ind.*, **33**, 523–39 (1914).
[2] *J. Soc. Chem. Ind.*, **33**, 1122–4 (1914).
[3] *Surveyor*, **46**, 681–2 (1914).
[4] *J. Soc. Chem. Ind.*, **33**, 1124–30 (1914).

this country, consulting with Fowler, experiments[1] were begun with F. W. Mohlman at the University of Illinois on November 2, 1914, using three-gallon bottles. On January 4, 1915, a tank 9 inches square and 4½ feet deep was put in operation. In the bottom of this tank was placed a porous plate made of material known as "Filtros," furnished by the General Filtration Company, Rochester, N. Y. Through the courtesy of the manufacturers a

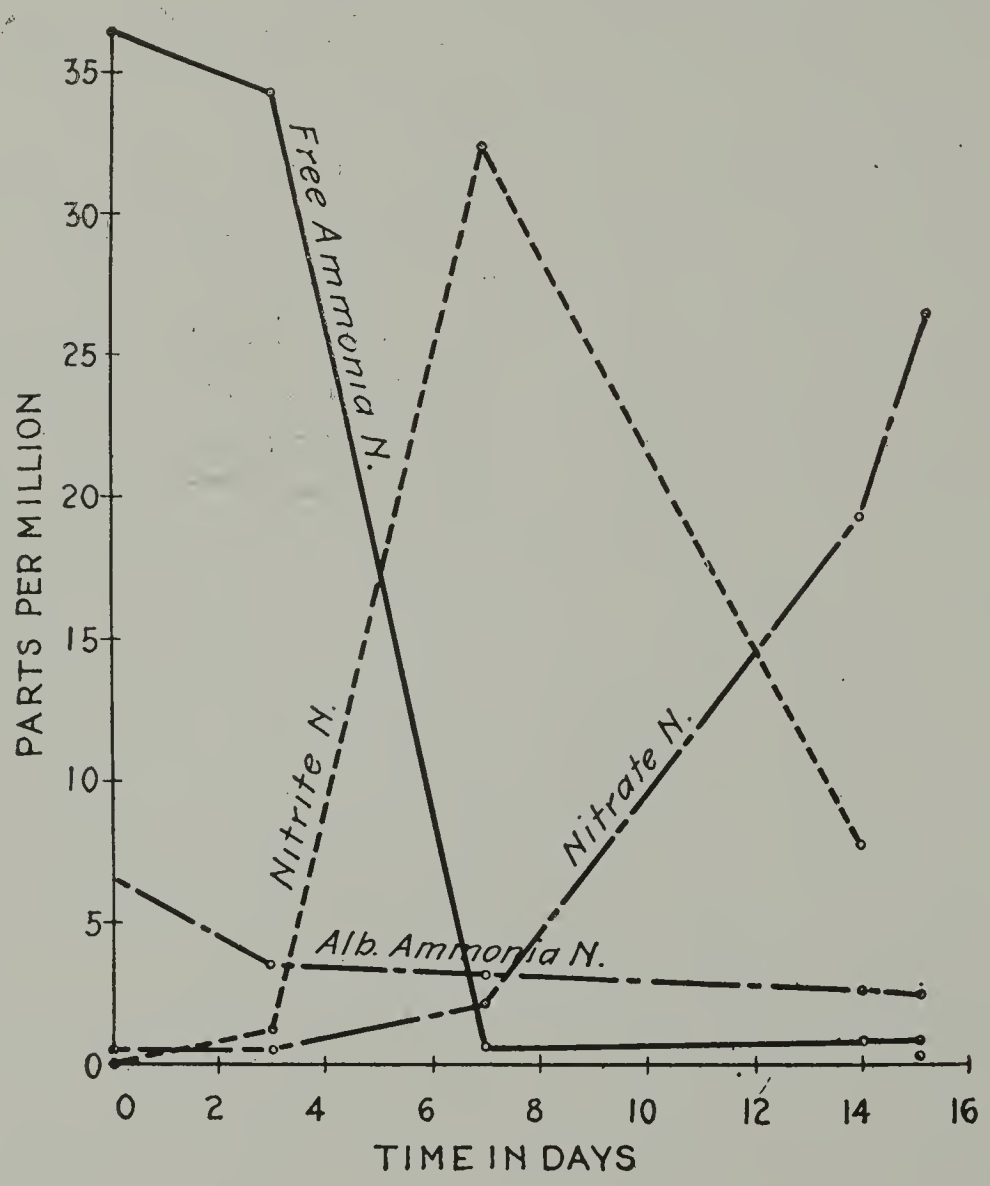


FIG. 1.

number of the plates were exhibited. The plates are made of a very pure and carefully graded quartz, fused together with powdered glass.

The results of our first experiments were similar to those of Ardern and Lockett. Sewage placed in the bottles or in the little tent of ammonia, nitrate, and nitrite nitrogen. Oxidation has been oxidize it completely. The oxidation is best measured by the con-

[1] *J. Ind. Eng. Chem.*, **7**, 318 (1915); *Eng. News*, **73**, 647–8 (1915); *Eng. Record*, **71**, 421–2 (1915); *Eng. Contrg.*, **43**, 310–1 (1915).

tent of ammonia, nitrate, and nitrate nitrogen. Oxidation has been carried to completion five different times with practically the same results. The time required for oxidation differed, but the courses of the reaction were similar. As an example in one of these experiments at the beginning 35 parts per million of ammonia nitrogen were present. (See Fig. 1.) The ammonia nitrogen remained practically constant for about four days and then quite rapidly decreased so that at the end of about seven days it was gone. There were no nitrates nor nitrites present in the raw sewage. The nitrites

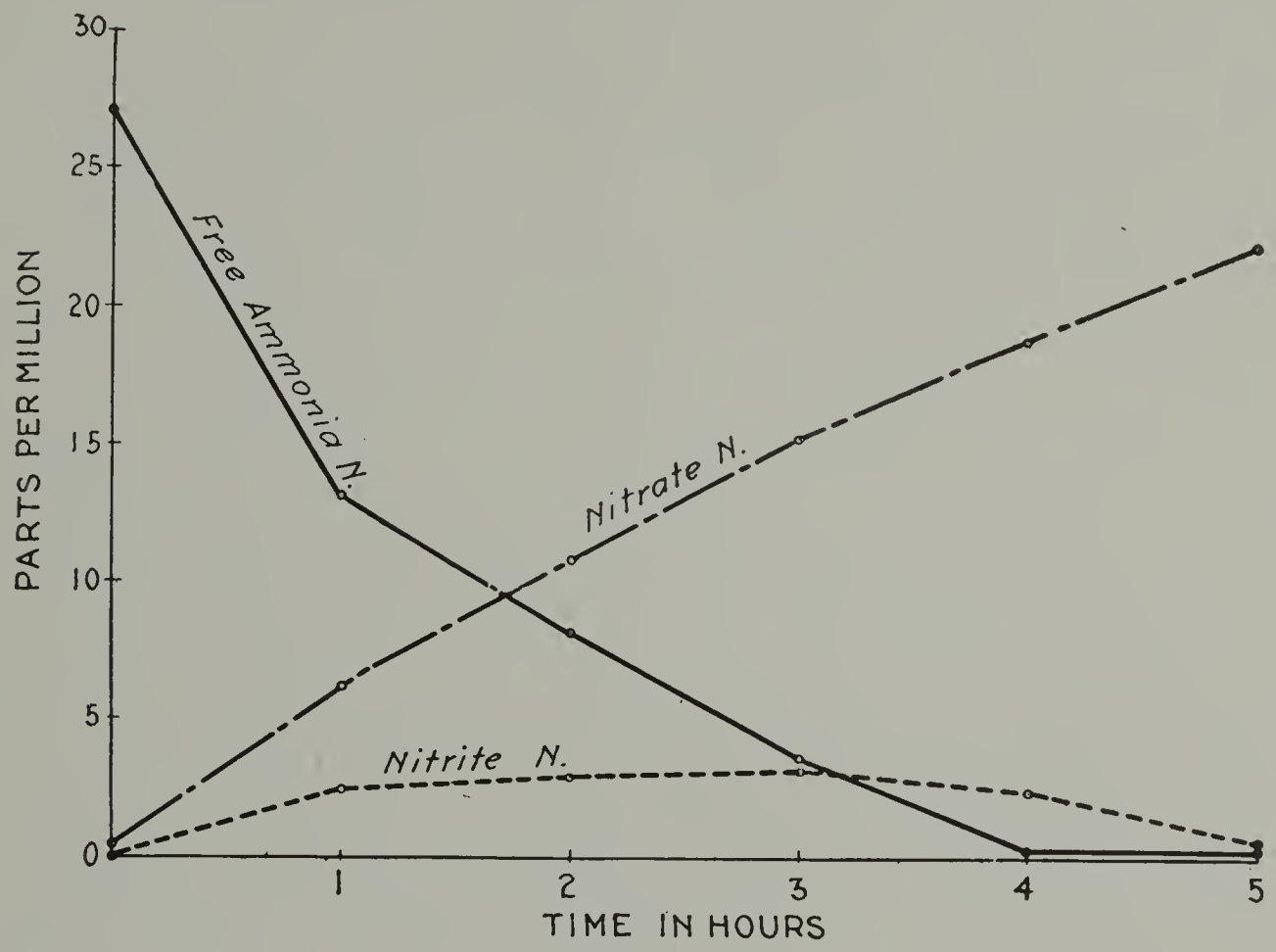


FIG. 2.

increased as the ammonia decreased. Then for a few days the nitrites remained constant and then decreased, the nitrates which were zero at the start increasing as the nitrites decreased. At the end of fifteen days, nitrification was complete, the nitrite nitrogen had practically disappeared and the nitrate nitrogen had increased to about 25 parts per million. When the oxidation was complete the supernatant liquid was replaced by fresh sewage, the sludge being left. This process was repeated. With each change less time was required for oxidation, as for example, fifteen days for the first, four days for the second, and two days for the third, and so

on, until with the thirty-first treatment oxidation was complete in five hours.

With accumulation of sludge as the process is repeated the reaction follows a different course, for example (See Fig. 2), using a sewage with 27 parts per million of ammonia nitrogen, the ammonia decreases and is practically eliminated in five hours. The nitrite nitrogen never increased to any extent, the nitrate nitrogen begins to increase almost at the start increasing as the ammonia nitrogen decreases, and reaches its maximum when the ammonia nitrogen has disappeared. It is not necessary to obtain complete nitrification to obtain a clear or stable effluent. More information must be obtained before the amount of nitrification required can be known.

The process is undoubtedly bacteriological. The sludge is very rich in bacteria but the number in the effluent is comparatively small. Mr. Robbins Russell investigated the bacteriological properties of the sludge. Several species of bacteria were isolated from the sludge including two kinds of nitrifiers and about fifteen other varieties. Experimenting with sterilized sewage it was found that the nitrifiers alone would not purify the sewage. Mixtures of the nitrifiers with the other bacteria would completely purify the sterilized sewage.

In an article which was presented before the American Chemical Society[1] mention was made of some worms which developed in the process and which were identified by Professor Frank Smith of the Zoological Department of the University of Illinois as Æolosoma Hemprichi. It seemed possible that these worms might play an important role in the purification process. Having isolated about two hundred of these worms as completely as possible from the bacteria and sewage, Mr. Russell added them to sterilized ammonia broth and aerated it, obtaining practically no nitrification. The worms are, therefore, not essential and the bacteria which were isolated from the sludge did nitrify sterilized sewage.

The fresh sludge is odorless. It will putrefy if left with a large amount of water. After filter pressing it is stable. The dried sludge has an odor similar to that of fertilizers. The sludge is rich in nitrogen, 4.0 to 6.4 per cent. Its value as a fertilizer has been shown by pot cultures, made by W. D. Hatfield, under the general direction of Professor C. G. Hopkins and with the assistance of

[1] *J. Ind. Eng. Chem.*, **7**, 318 (1915).

Mr. J. C. Anderson of the University of Illinois. The pot cultures are made according to a standard method. Each pot contains 19,820 grams of pure white sand, 60 grams of dolomite, 6 grams of bone meal, and 3 grams of potassium sulphate. That is, each pot contained an equivalent of 5 tons per acre of dolomite, one-half ton of bone meal, and 500 pounds of potassium sulphate. There is in the pots all of the constituents of a plant food except nitrogen.

Pot 1 contained no nitrogen. Pot 2 contained dried blood equivalent to 120 lbs. of nitrogen per acre. Pots 3 and 4 contained the equivalent of 120 pounds of nitrogen or one ton of sludge per

FIG. 3.—Pot Culture, Wheat Twenty-three Days after Planting.

Each pot contains pure white sand to which the same amount of plant foods except nitrogen have been added. No. 3 contains 20 g. dried activated sludge. No. 4 contains the same amount extracted with ligroin. No. 2 contains an equivalent of nitrogen from dried blood and No. 1 contains no nitrogen.

acre. Thirty wheat seeds were planted in each pot. In four days the plants were up in each pot and in ten days were five inches high. At the end of eighteen days each pot was thinned to fifteen of the best plants. A noticeable difference was observed after twenty-three days. (See Fig. 3.) The pots fertilized with the sludge grew very much more rapidly than any of the others. The difference at the end of nine weeks (see Fig. 4) was very marked. The differences seemed too great to be true so another series was planted. Similar results were obtained. (See Fig. 5)

Judgment of the results of such an experiment depend on the crop. In pot No. 1 the number of heads was 14 and the num-

ber of seeds 85, corresponding to 6.2 bushels per acre. In No. 2 fertilized with dried blood the number of heads was 15, seeds 189, corresponding to 13.6 bushels per acre. Dried blood is not a satisfactory fertilizer with some soils which may account for poor results. In pots 3 and 4 fertilized with the sludge, the num-

FIG. 4.—Pot Cultures, Wheat Sixty-three Days after Planting.

Each pot contains pure white sand to which the same amount of plant food except nitrogen have been added. No. 3 contains 20 g. dried activated sludge. No. 4 contains the same amount extracted with ligroin. No. 2 contains an equivalent of nitrogen from dried blood and No. 1 contains no nitrogen.

ber of heads was 22 and 23, the number of seeds 491 and 518, corresponding to 35.9 and 37.7 bushels per acre. A very fair yield of wheat. The check experiment gave approximately the same results, the number of bushels per acre being 35.1 and 36.0

The value of the sludge was tested with radishes and lettuce in the open field. Three plots each 2 feet by 3 feet were laid out. One plot was fertilized with extracted sludge, a second with sludge

and a third was not fertilized. Radishes and lettuce were planted in each. Thirty-eight days after planting the six best plants were taken from each plot. (See Fig. 6.) The difference in size was very marked. The fertilized lettuce weighed 40 per cent more than the unfertilized and the fertilized radishes weighed 150 per cent more than the unfertilized.

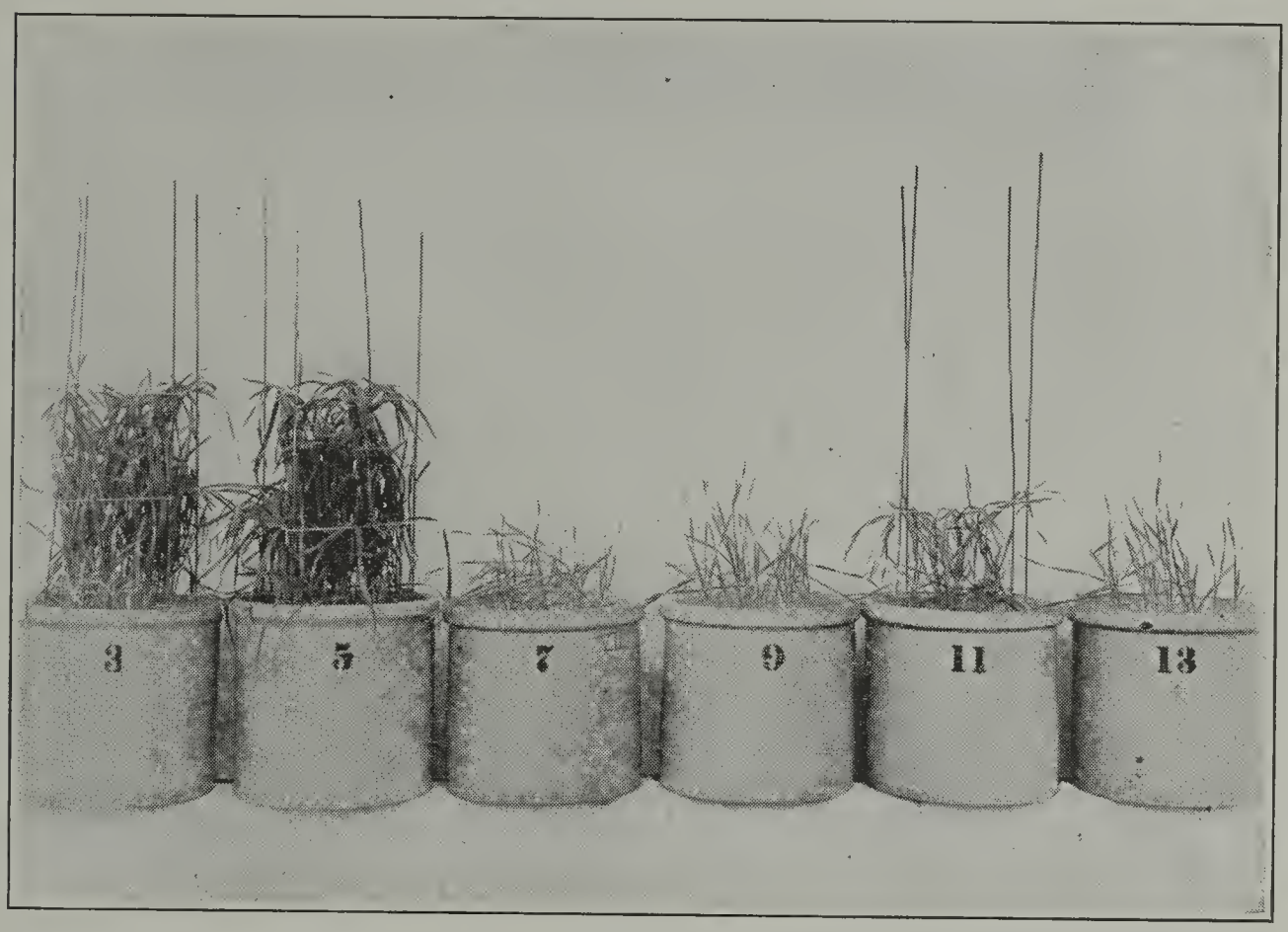


FIG. 5.—Pot Cultures, Wheat Series 2, Thirty-five Days after Planting.

Each pot contains pure white sand to which the same amount of plant foods except nitrogen have been added. No. 3 contains 20 g. dried activated sludge. No. 5 contains 20 g. of dried activated sludge from which ether-soluble matter has been removed. No. 7 contains the nitrogen equivalent from sodium nitrate. No. 9 contains the nitrogen equivalent from ammonium sulphate. No. 11 contains the nitrogen equivalent from gluten meal. No. 13 contains the nitrogen equivalent from dried blood.

Both the pot cultures and the gardening experiments show that the nitrogen in activated sludge is in a very available form and that the sludge is valuable as a fertilizer.

The process is attracting a great deal of attention in America, and a very good statement concerning the work being done is given in *Engineering News,* July 15.[1] Mr. M. N. Baker has given an

[1] *Eng. News*, **74**, 164–71 (1915).

editorial review of the subject. The most extensive work is being done at Milwaukee. An article by Mr. T. Chalkley Hatton[1] gives a more complete account of the Milwaukee experiments. Two tanks of 1 x 5 x 10 feet deep and one tank 10½ x 32 x 10 feet deep have been operated on the fill and draw plan and one tank 10½ x 32 x 10 feet deep is operated on the continuous plan. The Milwaukee Sewerage Commission has awarded contracts for the

FIG. 6.—Gardening Experiments Thirty-eight Days after Planting.

Radishes. From left to right, six radishes fertilized with extracted sludge, six radishes fertilized with sludge, six radishes unfertilized. Lettuce. Six heads fertilized with extracted sludge, six heads fertilized with sludge, six heads unfertilized.

construction of a plant to treat 2,000,000 gallons of sewage per day by continuous flow. At Baltimore they have been working on a small scale but have adapted two of the new Imhoff tanks for use by this process, and it is expected that in a short time they will be using activated sludge on a large scale. At Washington, the Hygienic Laboratory of the Public Health Service is experimenting

[1] *Eng. News*, **74**, 134–7 (1914).

on a small scale and is co-operating with the Department at Baltimore in their experiments. At Cleveland, experiments are being carried on in the sewage experiment station. They have adapted tanks 5 x 10 and 5 feet deep which they used in their sewage experiments to the process, and while it has barely begun they are getting promising results. Experiments are to be carried out on a larger scale. At Regina, Saskatchewan, experiments on a considerable scale have been carried out and their results are reported by R. O. Wynne-Roberts.[1] At Houston, Texas, they are planning to use the process in a plant to ultimately treat the sewage from 160,000 people. They do not expect to obtain complete nitrification as they do not believe that a completely purified effluent is necessary. In Chicago the Sanitary District of Chicago is using tanks about 2 feet in diameter and 8 or 10 feet high with quite satisfactory results, using the waste from the stock yards, one of the most difficult wastes that we have to treat. At the University of Illinois, Urbana, we are operating four tanks on the fill and draw plan. Each tank has an area of 10 square feet and a depth of 8 feet. About 400 gallons can be added to each tank at each filling. The bottoms are 1/9, 1/3, and all (in two tanks) covered with filtros plates to try to determine the best arrangement for the diffusion of air. Of the three schemes tried 1/3 of the bottom with the rest slanting toward the plates seems better than the other schemes.

A study of methods of developing sludge shows that sludge can be developed from raw sewage by changing the sewage every 6 hours. A full description of the plant and the experiments will be given in a later article.

From 1 to 2 cubic feet of air per gallon of sewage is needed and the cost of the air with electric current at 2 cents per kilowatt hour, we estimate will be from $5 to $8 per million gallons. At Milwaukee, where they are using a little more air, they estimate the cost of the air with electric current, at 1 cent per kilowatt hour, to be $1 per hour of aeration. If they aerate for four hours that would be $4 per million gallons for the cost of the air.

This method of sewage purification is giving such satisfactory results in the purification of sewage on a small scale under summer conditions, that it will be tried on a large scale and under winter conditions so that we ought to know by spring whether it is a success.

[1] *Canadian Engineer*, **29**, 112, 3 (1915).

DISCUSSION

The CHAIRMAN: You have heard this very interesting paper on a topic which is of the greatest general interest. Are there any questions or any statements in regard to this matter?

Mr. DRAKE: What is the idea with regard to the removal of fatty material?

Prof. BARTOW: We had an idea that the fat might have an inhibiting action on the fertilizer value of the sludge so that we extracted the fat or fatty material from the sludge and carried on the two cultures simultaneously.

Mr. DRAKE: Would the difference in fertilizer value take care of the cost of extraction?

Prof. BARTOW: There was practically no difference in the fertilizer value and from our experiments it would not look as if the increase in fertilizer value would pay for the extraction. The amount of extractive matter has varied from 4 to 10 per cent, but we have not gone into the matter far enough to know whether it would pay to extract the material for the fat present. If we can save say 10 per cent of fat it might pay.

Prof. REID: What percentage of the original nitrogen turns up in the dry sludge?

Prof. BARTOW: That is a matter that I am unable to determine as yet. We change considerable of the ammonia introgen to nitrate which goes off into the sewage. We have been endeavoring to determine the amount of sludge which we get per million gallons. At our plant, which I didn't have time to describe, we are handling about 6000 gallons of sewage per day, keeping account of the sewage and of its strength and measuring the sludge taken off. The amount of sludge in warm weather at least is quite small, much less than we had expected, much less than we obtained during the colder weather. The amount of nitrogen that can be saved is still to be determined.

Prof. WITHROW: How about temperature?

Prof. BARTOW: We have been running our experiments at the ordinary temperature in the basement of the boiler house at the University. The temperature of the sewage is approximately 70° F. The plant is underground and the temperature doesn't

rise very much. Fowler states that the best temperatures are from 10° to 30° C.

Prof. ENDERS: Are the remaining 1 per cent of bacteria nitrifiers?

Prof. BARTOW: I cannot tell you the kind of bacteria present in the effluent. The effluent is clear without filtration and the number of the bacteria reduced we will say from 3,000,000 in the raw sewage to less than 30,000 in the effluent.

A NEW ELECTROLYTIC METHOD OF SEWAGE DISPOSAL

By J. C. OLSEN.

Read at the Los Angeles Meeting, at the Joint Session with the Southern California Section of the American Chemical Society, August 18, 1915.

The process of sewage disposal described in this paper has been in operation at Elmhurst in New York City for more than a year.

At the plant in New York City a 25,000-gal. unit was in operation for several months and was very thoroughly tested by several chemists, sanitary and electrical engineers. This unit was designed for water treatment rather than for sewage, but the results were so satisfactory that a 500,000-gal. unit was built and has been in continuous operation since early in April. During this time an average of about 750,000 gal. of sewage has been treated daily, although the unit was constructed for 500,000 gal. For about three months after it was installed, tests were carried out almost continuously by the author, in conjunction for most of the time with Prof. William P. Mason, Dr. C. O. Mailloux and Mr. P. M. Travis. Dr. Mailloux made most of the electrical observations and deductions, while the chemical and bacteriological tests were made by Professor Mason, Mr. Travis and the author, assisted by Mr. William H. Ulrich. The work involved the taking of about 200 samples and their chemical and bacteriological analyses as well as a very large number of observations of current consumption.

The process and apparatus used was invented and patented by Mr. C. P. Landreth of Philadelphia and will, no doubt, become known as the Landreth electrolytic process of sewage disposal. The electrical purification of sewage has been attempted before in various ways and is or has been in use at a number of localities, notably Oklahoma City, Okla., and Santa Monica, Cal.

Mr. Landreth's process seems to be new in that he uses lime together with electrolysis for the treatment of sewage and also in that he uses a much smaller quantity of electricity per gallon than others have employed.

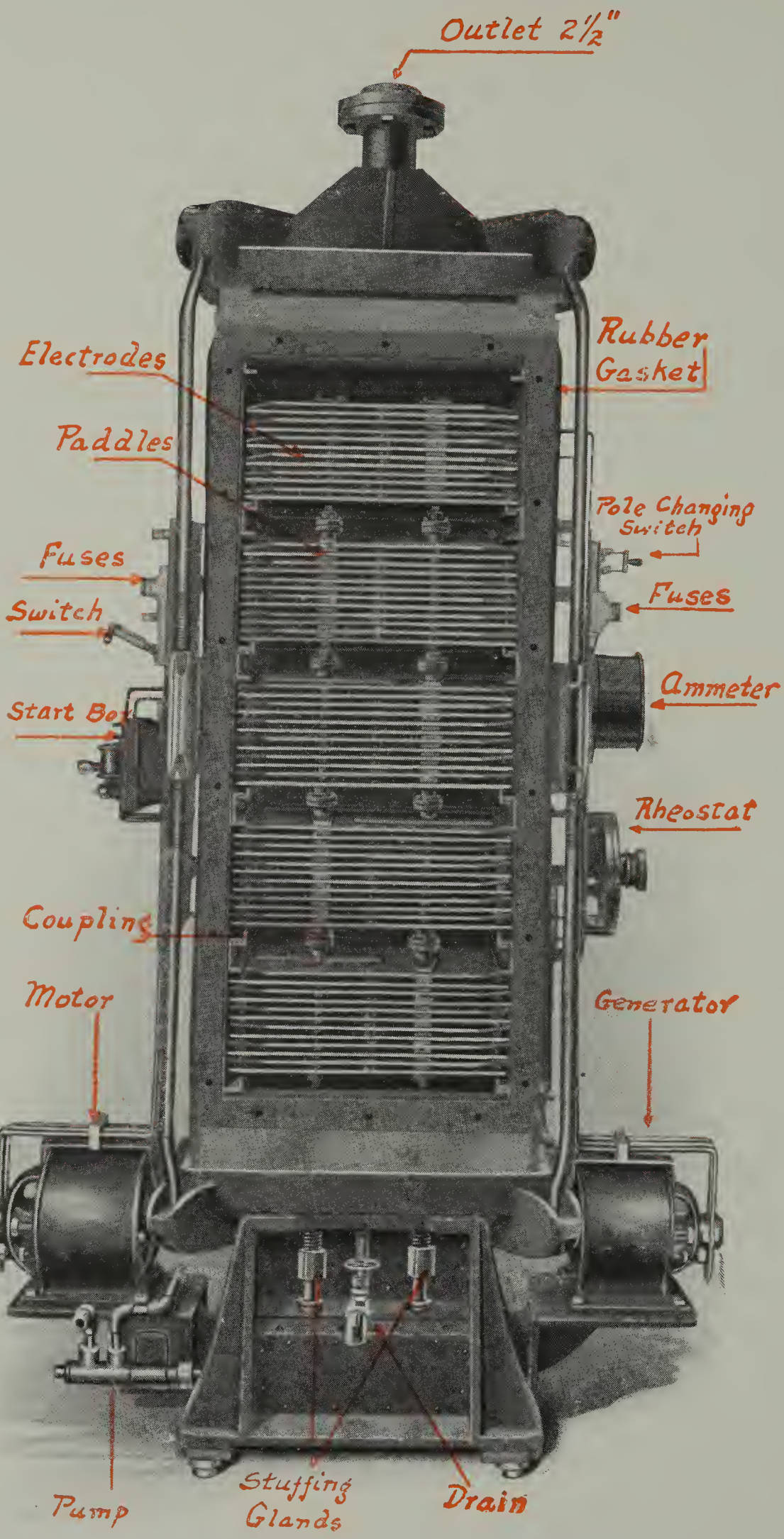


FIG. 1.—Electrolytic Apparatus with Door Removed, Showing Electrodes and Paddles (25,000-gal. unit).

Electricity alone has been used before as well as lime alone, but the combination of these two agents accomplishes what neither of them alone can effect. The Landreth process also employs a very thorough system of agitation.

The process as in use at Elmhurst comprises the following principal stages of operation: (1) screening; (2) electrolytic treatment with addition of lime; (3) sedimentation; (4) filter pressing of sludge.

The raw sewage is delivered by the mains into a receiving well from which it is pumped through quarter-inch screens by means of a centrifugal pump through the electrolytic machine.

The electrolytic machine consists of a horizontal wooden box 23 ft. 3 in. long, 3 ft. in width, and 2 ft. 8¾ in. in depth. It rests upon a masonry foundation 18 in. high. The sides, top and bottom of the box are stiffened by means of angle irons. The top of the box is in two equal sections bolted on, the joint being made tight with a rubber gasket. The top may be removed for cleaning or for the inspection of the electrolytic apparatus.

A series of valves at the bottom serve to remove any sludge which may accumulate in the box.

The sewage to be treated is forced through the apparatus by the pump which takes it from the receiving well and delivers it to the inlet of the apparatus at one end. In passing from the inlet to the outlet (at the other end) of the apparatus, the sewage flows between numerous plates which are placed parallel and close to each other inside the closed box. Consequently the liquid does not flow in one mass, but is subdivided into a large number of relatively thin "sheets." The plates which separate these sheets of sewage from each other also serve as electrical conductors or "electrodes" by means of which electrical currents capable of producing electrolysis are conveyed across the liquid sheets, through the sewage with the result that one side of each liquid sheet is in contact with an "anode" surface, and the other with a "cathode" surface. To insure thorough agitation of the sewage, as it flows in the spaces between the electrode plates, mixers in the form of paddles placed between these plates are rotated in the plans of each liquid sheet.

The plates inside the apparatus are all in a vertical plane, parallel with the sides of the tank, so that the "liquid sheets" of flow between the plates are all vertical. These liquid sheets are not con-

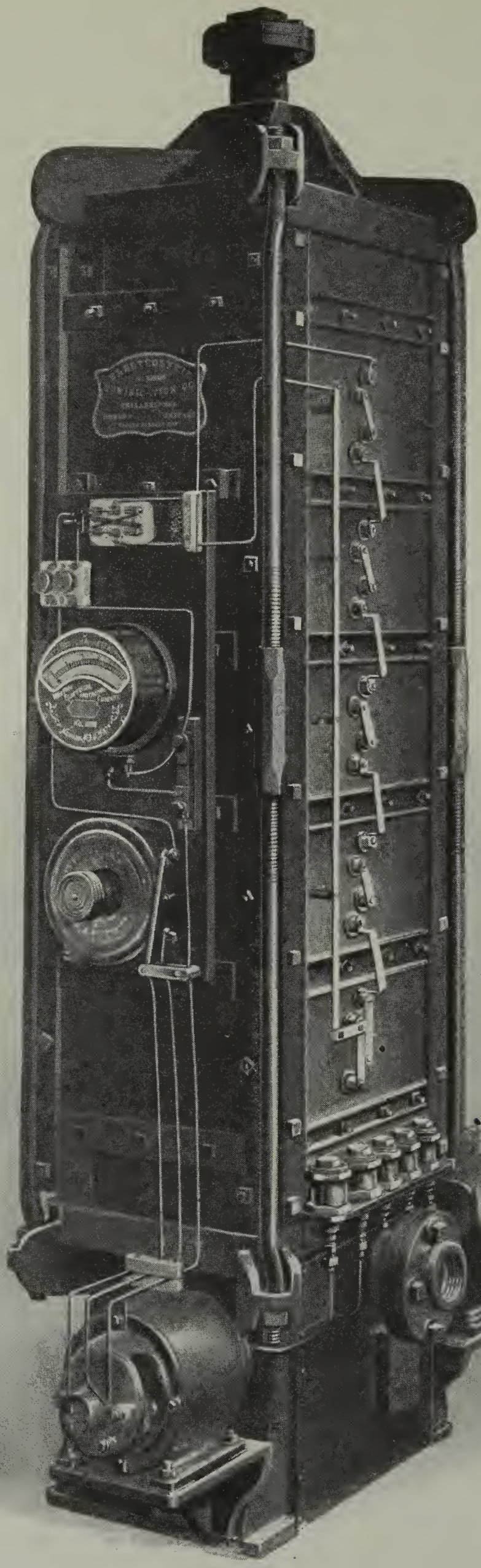


FIG. 2.—Outside View of Electrolytic Apparatus, 25,000 Unit.

tinuous from the inlet to the outlet ends of the apparatus, because the plates are arranged in groups with spaces left between them.

The plates are of iron, and are all of the following dimensions: length, 16 in.; height, 10 in.; thickness, from 1/4 in. to 3/16 in. The plates are grouped and assembled in sets, like the plates for an "element" or cell of a storage battery. The plates in each group are all parallel to each other, and they have equal spaces between them (5/16 in. to 3/8 in.). They are held together by bolts, which pass through all the plates, and through the insulating separators between them, and clamp them into a solid unit.

When the groups are in position in the tank, these bolts extend across the tank horizontally and support the plates, which are then all in a vertical position, parallel with the sides of the tank, and occupy the entire available space across the tank. A group contains fifty plates (except in a few cases where the number is one or two less). There are groups at eleven places or divisions in the tank between the inlet and the outlet; and there are two groups at each place, one above the other.

This makes a total of twenty-two groups and (nearly) 1100 plates.

The two bolts just mentioned are also utilized as electrical terminals and conductors for the plates. This is done by insulating the even-numbered plates from one bolt and connecting the odd-numbered plates with it, and doing the opposite for the other bolt.

This is the arrangement used for the groups in the first section (counting from the inlet) and in the last six sections, or for a total of fourteen groups. In these groups the plates constitute, in each case, an "electrolyzing element" of twenty-five pairs of plates.

In the other four divisions the arrangement is less simple. The fifty plates of each group are not electrically grouped and connected into a single element of twenty-five pairs of plates, but into three elements, each of eight pairs (or more), which are connected in series. It follows that the total number of "elements" in these four sections is twenty-four (i.e., twelve for the four upper groups and twelve for the four lower groups). Adding these to the fourteen elements in the other divisions, the total is thirty-eight elements.

In most of the tests the thirty-eight elements were all connected in a simple series; in one test the nineteen elements in the

upper tier were connected by themselves in series, and likewise the nineteen elements in the lower tier; and the two series were then connected in multiple. Various other combinations of series and multiple connection may be made and were made in some of the tests.

When all the thirty-eight elements are connected in series, there is a difference of three to one in the current density at the "large"

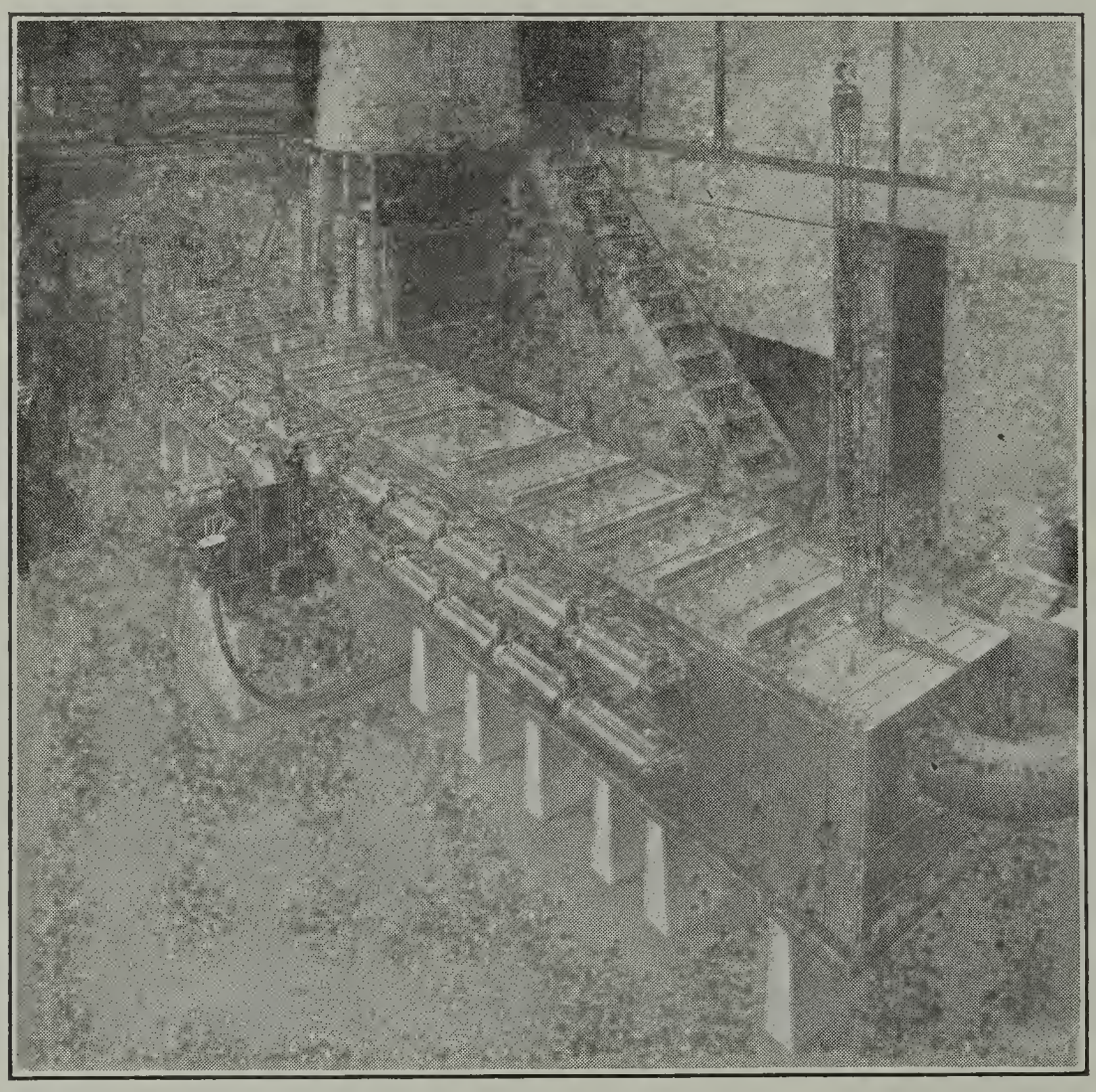


FIG. 3.—Horizontal Electrolytic Apparatus (500,000 gal. Unit) Installed at Elmhurst, New York City, Motor and Reduction Gearing for the Mechanical Stirrers Shown on Left-hand Side of Machine.

elements (composed of twenty-five pairs) and at the "small" elements (composed of eight pairs). The same current passes (theoretically) through all the elements, and as the electrode surface is three times greater at the large elements than at the small elements, the current per unit of surface will be only one-third as great at the large elements as at the small elements.

SOURCE OF CURRENT. The current supply required for producing electrolysis is obtained from a direct-current generator of 5-kw.

capacity, which is direct driven by an alternating-current induction motor.

The maximum current capacity of the generator is 40 amp. and its maximum voltage is 125 volts. A watt-hour meter was especially connected in the mains between the generator and the switchboard for the purpose of the test to enable the direct-current output in watt-hours to be computed for given periods of time in connection with the test.

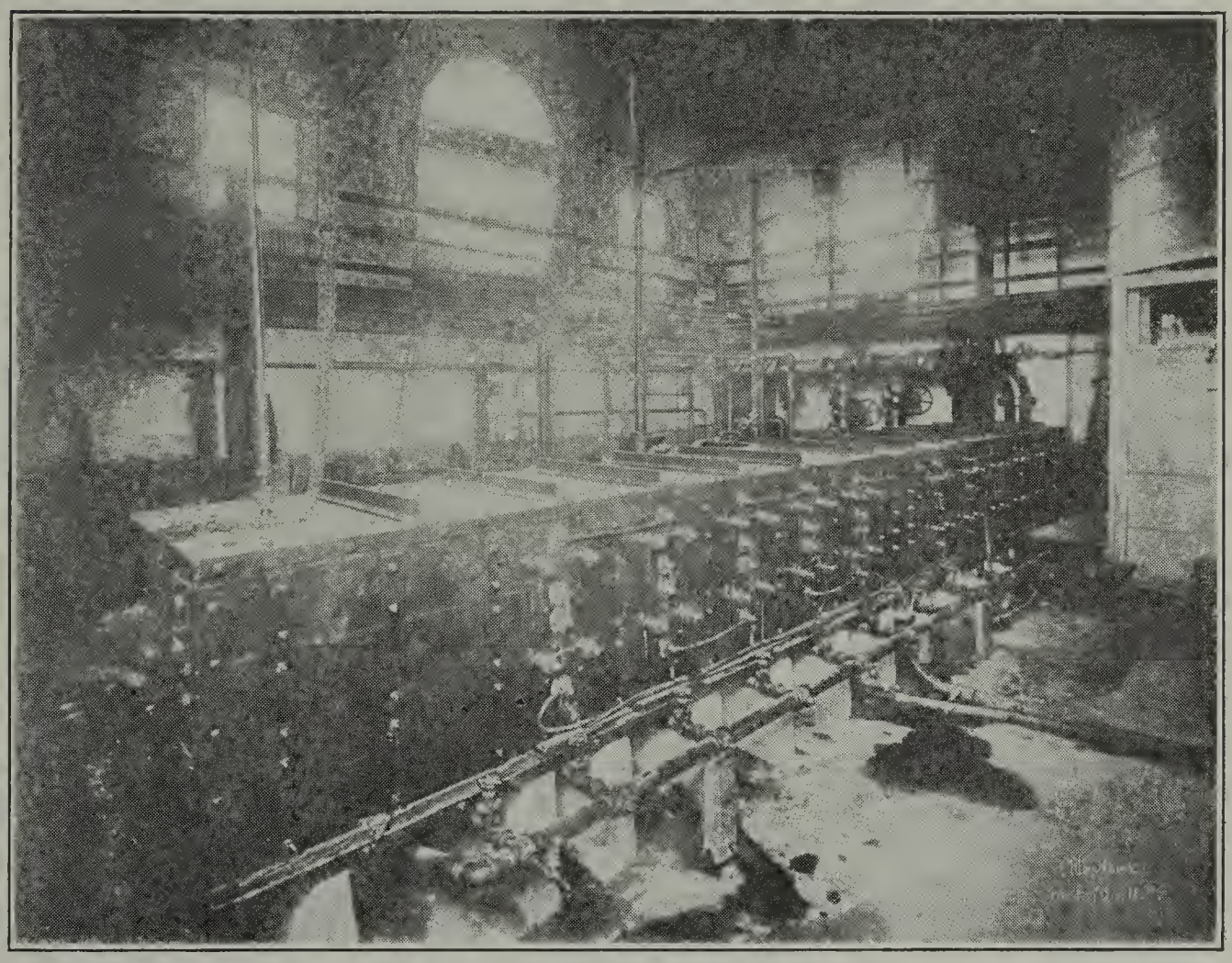


FIG. 4.—Horizontal Electrolytic Apparatus Installed at Elmhurst, Showing Electrical Connections on Right-hand Side of Machine.

AGITATION OUTFIT. In addition to the two holes in the electrode plates for the bolts which serve to hold them together there are two other holes which make openings for the shafts upon which the paddles rotating in the spaces between the electrode-plates are mounted. There are two rotating shafts passing through each group of plates, and each shaft carries forty-nine paddles. This makes ninety-eight paddles per group of plates, or a total of 2156 paddles for the twenty-two groups. The forty-four shafts are

supported in bearings mounted on the sides of the tank. They pass through the side of the tank, and are driven by bevel gearing from four horizontal shafts, which receive power from a 3-hp. induction-motor through reduction gearing.

There is a double reduction-gear by which the speed of the clutch-shaft is reduced to seventy-eight when the motor speed is 1800. The horizontal shafts are geared to run at half this speed, and the paddle shafts are geared to run at half the speed of the horizontal shafts. Hence, if the motor ran without slip the paddle shafts would have a speed of 19.5 r.p.m. Actual test showed that the speed of the paddle shafts was from 18 to 19 r.p.m., according to the "load" on the motor, which at times appears to be relatively heavy, as indicated by the rise of temperature of the motor. The increase in load appears to be due to increased friction between the paddles and the electrode plates, owing to deposits on the plates.

The amount of flow of sewage through the machine was measured by a Venturi indicating and recording meter connected in the discharge pipe leading from the machine to the sedimentation tank.

The milk of lime added to the sewage is prepared by putting quicklime or hydrated lime in a vat with water and agitating the mixture by electric power, produced by a ½-hp. motor. The electric current supply required for operating the pump motor, the lime vat motor and the motor generator is taken from the street mains through watt hour meters.

METHOD OF OPERATION. The milk of lime is introduced into the sewage in several different ways. A small centrifugal pump operated by an electrical motor was at times used to force the milk of lime into the inlet of the electrolytic machine through a suitable pipe, the amount of flow being regulated by a valve on this pipe. A pipe was also provided by which the milk of lime could be forced into the sewage at the outlet of the machine.

The milk of lime was also at times forced into the sewage through a pipe leading to the inlet of the sewage pump. In the latter case the mixture of the milk of lime with the sewage was affected by the action of the pump.

The electrolyzing current was maintained as nearly constant as practicable, the voltage of the direct-current generator being regulated at the switchboard whenever any variation in the current was observed. The "polarity" of the current was reversed about every hour, with the object of equalizing any chemical action

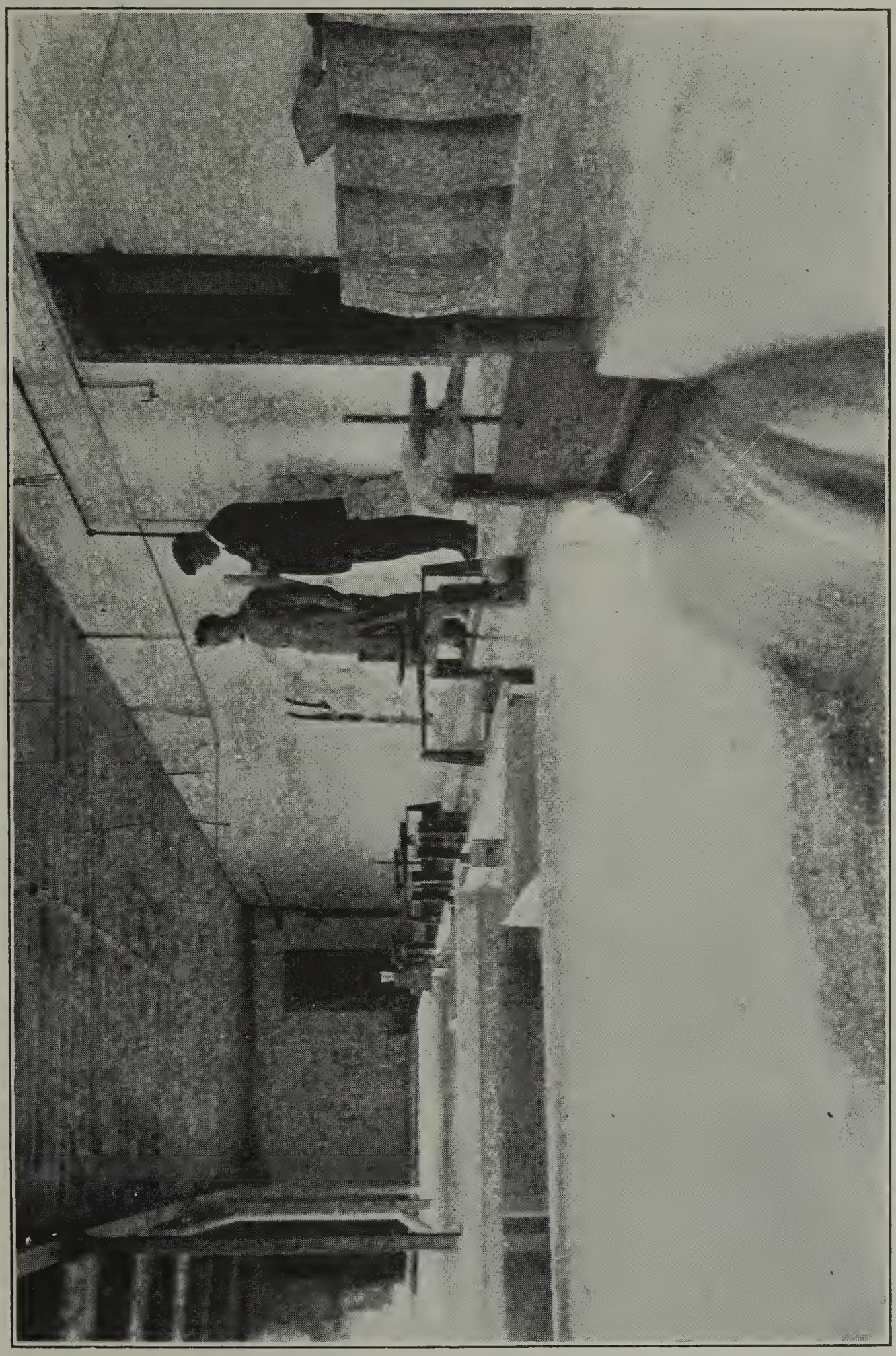


FIG. 5.—Sedimentation Tanks and Overflow of Purified Sewage.

that may be produced on the iron electrodes, and preventing the formation of deposits there. A very considerable drop in voltage occurred on reversing the polarity, after which the voltage increased again and after about 15 min. was again normal. The volume of electrical current (amperes) sent through the apparatus varies with the mode of connection of the electrodes. With all the thirty-eight elements connected in simple series, the current through the circuit was generally maintained at about 30 amp. This is the way in which the apparatus has been principally operated.

On one occasion, the elements in the upper and lower tiers were respectively connected in series, and the two series were connected in parallel. This would give nineteen elements in series, each element being composed of two elements in multiple. The current passing through these series on that occasion was maintained at 40 amp., which was the limit of current output of the direct-current generator.

The voltage of the generator must be equal to the sum of the "voltage-drops" at all points in the entire working circuit, including the leads, the electrolyzing elements, and their connections. The voltage-drop at the electrolyzing elements is the factor which, multiplied by the current (amperes) passing through the elements, gives the electrical energy expended directly upon the liquid. The voltage, or potential difference, per element, depends upon the counter-electromotive force, and the polarization incidental to the electrolysis produced, and upon the electrical resistance of the liquid. These conditions, in turn, depend on, and are affected by the chemical constitution, the density ("strength"), and the temperature of the liquid.

Theoretically the voltage per element should be the same for all sets of electrodes of the same kind (*i.e.*, having the same number and size of plates, etc.), under the same working conditions. Practically, it is found that the voltage per element varies even with plates of the same kind and size, in consequence of changes in the conditions. Deposits are produced on the plates, which alter the amount of active surface of the electrodes, or decrease the thickness of the sheet of liquid flowing between the plates; and chains and bridges of solid matter may at times form between plates of opposite polarity, causing the current to be shunted in part or even short-circuited entirely. Tests made while the apparatus

was in operation show that the voltage per element varies appreciably from such causes.

ELECTROLYTIC ACTION PRODUCED PER UNIT VOLUME OF SEWAGE TREATED. The total quantity of electric current sent through a unit volume of the sewage passing through the machine depends (a) upon the total volume of current or the aggregate sum o the electric currents passing through the elements and (b) the speed of flow of the liquid to the apparatus.

The total quantity of current is equal theoretically to the product of the number of elements connected in series by the current in amperes passing through the series. Thus, with a current of 30 amp. passing through all the thirty-eight elements in series, the total quantity of current would be equal to 1140 amp. on the assumption that there is no loss by leakage or shunt ng past any of the electrodes in the middle portion of the series.

The length of time that the liquid is subjected to electric action depends upon the length and sectional area of the path through which the sewage flows in passing through the apparatus and the rate of pumping, or the speed of flow through the apparatus.

The time of flow through the apparatus, when in operation, under given actual conditions, was determined by injecting a coloring substance into the liquid at some point ahead of the inlet, and then noting the time which elapsed until the color appeared at the outlet of the apparatus. It was found that when the speed of flow through the apparatus (as indicated by the Venturi flow-meter) was at the rate of 765,000 gal. per day, the time of flow through the apparatus was 1 min. 8 seconds, or 68 seconds. Allowance should be made for the time elapsing while the liquid is passing through the inlet and outlet, and through portions of the apparatus at which there are no electrodes. The actual time that the liquid was passing through the machine did not probably exceed 1 min. (60 seconds).

A rate of flow of 765,000 gal. per day is equal to 531.2 gal. per minute. Allowing for 10 per cent leakage, a current of 1140 (or 1026 net) amperes acting during 1 min. represents 61,560 coulombs. The quantity of electric current applied, in 1 min., to the liquid, is

$$\frac{61,560}{531.2} = 116 \text{ coulombs per gallon.}$$

This quantity will obviously vary inversely with the rate of flow. Thus, if the rate of flow were increased to 1,000,000 gal. per day, the coulombs per gallon would fall down to 88; and if the rate of flow were decreased to 600,000 gal. per day, the coulombs per gallon would increase to 148. Under these conditions, and taking into account all causes of variation, the quantity of electric current per unit volume of sewage treated may range, in round numbers, between 80 and 150 coulombs per gallon, or 21 to 40 coulombs per liter. In the tests actually made, the electric current ranged between 19.5 and 40.9 amp. according to connections and other conditions of the tests; and the current per unit volume was from 85 to 169 coulombs per gallon (22.5 to 44.7 coulombs per liter). When extreme and unusual conditions are excluded, the figures are likely to remain within the limits just mentioned.

This quantity of electricity will, theoretically, liberate from 0.00174 to 0.00332 gram or 1.21 to 2.31 cu. centimeters of oxygen per liter of sewage treated.

CURRENT-DENSITY. In fourteen sets of electrode-plates all the plates of the set (forty-eight to fifty in number) are connected electrically so as to make one single electrolyzing element of twenty-four (or twenty-five) pairs of plates. In the other eight sets the plates are connected electrically so as to constitute three electrolyzer elements of eight pairs of plates, and the three elements are connected in series. The theoretical active electrode surface in the "single" elements (of twenty-four pairs) is three times greater than in the "triple" elements (of eight pairs). Hence, with the same current passing through "single" and "triple" electrodes (as when they are connected in single series) the current-density in amperes per square foot of active electrode surface, is only about one-third as great at the "single" as at the "triple" electrolyzer elements.

Each electrode-plate is 16 in. in length and 10 in. in height, which gives an active surface of 160 sq. in. on each side, from which must be deducted the loss of active area due to holes in the plates (for the shafts on which the "paddles" are mounted) and to insulating separators. An allowance of 10 sq. in. is made for this deduction, which leaves 150 sq. in. per side. Both sides of each plate are active, except at the two outside plates, which have only one active surface. The active surface of the larger electrolyzer elements (of twenty-four pairs of plates) is $23\frac{1}{2} \times 300$ or 7050 sq. in.,

equivalent to 48.9 sq. ft. The active surface of the smaller electrolyzer elements (of eight pairs of plates) is $7\frac{1}{2} \times 300$, or 2250 sq. in., equivalent to 15.6 sq. ft.

When all the electrolyzer elements in the apparatus (C-24) were connected in series (making thirty-eight in series), the electrolyzing current is maintained at about 30 amp. The maximum current capacity of the direct-current generator is 40 amp. With an electrolyzing current of 30 amp., the current-density will be equal to the following values:

For large units:

30/7050 = 4.25 milli-amp. per square inch, or,

30/48.9 = 0.61 amp. per square foot.

For small units:

30/2250 = 13.33 milli-amp. per square inch.

30/15.6 = 1.92 amp. per square foot.

With 40 amp. these values would be one-third greater.

For large units:

40/7050 = 5.67 milli-amp. per square inch.

40/48.9 = 0.82 amp. per square foot.

For small units:

40/2250 = 17.8 milli-amp. per square inch.

40/15.6 = 2.56 amp. per square foot.

The range of variation of current-density in round numbers is within the following limits:

For large units:

From 4 to 6 milli-amp. per square foot.

From 6/10 to 8/10 amp. per square foot.

For small units:

From 13 to 18 milli-amp. per square foot.

From 1.9 to 2.6 amp. per square foot.

SEDIMENTATION. In the operation of the process, two sedimentation tanks are used. The sewage, after it has passed through the machine (or through the by-pass, if that be used), is discharged into a flume about 3 ft. wide, which connects with the inlet of the sedimentation tanks in the tank room.

After the sewage has received its dose of lime and has been electrolyzed in the machine, it is passed through the above-mentioned flume in a stream, about 6 in. deep, into two settling tanks (each 82 ft. 6 in. × 20 ft. × 5 ft. 3 in., of about 65,000 gal. capacity, and provided with a baffle at the center rising from the bottom,

and also with a deep hanging baffle at the entrance and a skimming baffle at the exit, and from the second of them the settled effluent is finally discharged). These tanks are connected in tandem. The sewage enters the first tank at one end and passes through a gate into the second tank at the farther end. The time for sedimentation in each tank is nearly two hours or four hours for total time of sedimentation, dependent upon the rate of sewage flow. The effluent is discharged from the second tank through a flume by which it is conveyed to the discharge pipe.

It is proper to note that these sedimentation tanks were constructed for sewage disposal by the septic process previously in use at Elmhurst. Suggestions have been made for a new type of sedimentation tank and a model embodying some of them has been constructed, with which it is expected that more rapid and perfect sedimentation will be obtained.

Filter Press. Pipe connections of suitable diameter, leading from the bottom of the sedimentation tank, serve to convey the sludge to a receiving basin in the press room whence it is pumped to the filter press, which is of the Johnson type. Attention should be called to the fact that the filter press is not an essential part of the apparatus, as other methods of disposing of the sludge may be adopted.

Experiments Using Lime and Current. The first series of experiments were carried out for the purpose of ascertaining the effect of the operation of the machine with the addition of lime on the character of the sludge and the effluent. The machine was operated under what may be termed normal conditions. Lime was introduced into the sewage before passing through the machine in quantities equal to 1000 to 1300 lb. per 1,000,000 gal., which is equivalent to $7\frac{1}{2}$ to $9\frac{1}{2}$ grains per gallon. The quantity of lime used was ascertained by the tank being filled with milk of lime of known strength. Titrations were also made of the effluent to ascertain the amount of calcium oxide present in excess over that required to react with the dissolved carbonic acid and the alkalinity of the sewage. The current varied in different tests and ranged from 19.5 to 40.9 amp. This amount of current represented a range of 22.5 to 44.7 coulombs per liter treated (85 to 169 coulombs per gallon). This quantity of electricity will liberate theoretically from 0.00174 to 0.00332 gram per liter or 1.21 to 2.31 c.c.

Samples were taken of the raw sewage designated as A, of

the inflow to the sedimentation tanks designated as B, and also of the effluent from the sedimentation tank designated as C. Several samples designated as D were also taken of the outfall into the stream at a point several hundred feet distant from the buildings of the plant. These samples were used for the determination of physical appearance, chemical composition, count of bacteria, dissolved oxygen and putrescibility. Samples of sludge were also taken from time to time for examination with reference to putrescibility.

Table I gives the average of a considerable number of analyses of the samples taken at the four points indicated.

TABLE I

AVERAGE OF THE ANALYSIS OF RAW AND PURIFIED SEWAGE BY ELECTROLYTIC PROCESS

Results Given in Parts per Million

	RAW SEWAGE.	PURIFIED SEWAGE.		
	Sample *A*.	Before Sedimentation Sample *B*.	AFTER SEDIMENTATION	
			Sample *C*.	Sample *D*.
Nitrogen as				
Nitrites	0	0.84	0.13	.....
Nitrates	0.02	2.22	3.8	.....
Free ammonia	26.5	20.0	13.6	.....
Total organic nitrogen	13.8	9.2	5.5	.....
Oxygen				
Dissolved	1.62	2.92	3.94	8.35
Per cent of saturation	13.89	26.59	38.38	80.11
Consumed	42.8	36.4	20.7	.....
Turbidity	41	27	7.2	.....
Color	47	37	19	.....
Chlorine	67.6	71.2	70.5	.....
Carbon dioxide	21.28	0	0	.....
Calcium oxide	0	128.3	80.3	.....
Alkalinity	291.7	174.4	80.75	.....
Calcium carbonate	.....	294.8	95.3	.....
Bacteria count by agar	288,000	46,256	471	169

The amount of oxygen liberated by the electric current was relatively small. It ranged from 1.74 to 3.32 mg. per liter of sewage treated, which is equal to 1.21 to 2.31 c.c. per liter.

It will be noted that the nitrates increase from 0.02 in the raw

sewage to 2.22 in sample B and to 3.8 in sample C, which indicates oxidation of the nitrogen of the sewage.

The percentage of ammonia decreased from 26.5 to 20 and 13.6 respectively in samples B and C. Undoubtedly, ammonia is lost both by oxidation and volatilization.

The percentage of organic nitrogen decreased from 13.8 in the sewage to 9.2 in sample B. This disappearance of organic nitrogen is, no doubt, partly due to oxidation brought about by the anodic oxygen and partly to precipitation by the lime in the sludge as it was found to contain a considerable amount of nitrogen. The decrease in organic nitrogen continues between B and C, which is probably due partly to further precipitation in the sludge and partly to further oxidation. In this manner 60 per cent of the organic nitrogen is removed from the sewage. This large reduction of the organic nitrogen is an important factor in this method of sewage purification.

The oxygen consumed decreases from 42.8 to 36.4 to 20.7, which indicates removal of a large proportion of the dissolved and suspended organic matter.

The per cent of saturation of dissolved oxygen increases from 13.89 to 26.59 and 38.38, which is a total increase of 34.49 per cent.

The bacteria count decreased 84 per cent between A and B, and 99.83 per cent between A and C, which indicates a high degree of purity in the effluent.

A considerable amount of the organic matter is no doubt precipitated with the lime in the sludge, and this accounts for some of the changes noted. A considerable number of the bacteria are no doubt removed in this manner. The flocculation and precipitation of the sludge is very rapid after electrolysis and is much more rapid and complete than when lime only is used. This is probably due to the fact that the organic matter in the sewage is present as a colloidal solution which the electrolysis precipitates.

A comparison of the composition of sample C (which was taken after sedimentation, which, in this plant occupied about 4 hrs.) with samples B and A shows that the differences noted between A and B have become more pronounced, that is, nitrates and dissolved oxygen continue to increase; an exception is found in nitrites which decrease. The remaining constituents decrease in quantity, namely: ammonia, organic nitrogen, turbidity, color, alkalinity and bacteria. Carbon dioxide naturally remains absent

in the presence of free lime. The decrease in free lime and in alkalinity is due to the fact that the reaction between the lime and the calcium bicarbonate and other alkaline salts in the sewage requires several hours for its completion, and that it is for a time supersaturated with respect to some of the salts formed. The ammonia, no doubt, slowly volatilizes and considerable amounts of atmospheric oxygen are absorbed during sedimentation. The reduction in turbidity and color is, no doubt, due to precipitation.

A number of tests were made on the overflow from the sedimentation tank (sample C) after it had passed through a pipe several hundred feet long and was discharged into a stream flowing from the plant. The time required for this flow was estimated to be about 15 min. The dissolved oxygen rose from about 40 per cent to about 80 per cent while the bacteria count fell from 471 to 169. These results indicate the great purity of the effluent. There could not be any readily oxidizable organic matter in a water which will absorb oxygen so quickly and hold 80 per cent of its saturation value. The drop in bacteria content points to the same conclusion. This was confirmed by allowing samples of this effluent to stand in the laboratory and making bacteria tests on succeeding days. The bacteria count steadily decreased for as long as 9 days.

TABLE II

STABILITY OF EFFLUENT FROM ELECTROLYTIC PROCESS

As Represented by the Number of Bacteria per c.c. After Plating on Agar

A	*B*	*C*
	At time of taking sample	
	3	170
	After standing 24 hours	
	0	21
	At time of taking sample	
	30,000	400
	After standing 2 days	
	1,820,000	
	After standing 9 days	
		37
	At time of taking sample	
550,000		103
	After standing 4 days	
620,000		24

The quantity of lime added varied considerably during the course of the investigation, the average being about 1300 lb. of hydrated lime (72 per cent CaO) per million gallons. This is equal to about 113 parts calcium oxide per million or 6.6 grains per gallon.

A considerable proportion of this lime reacted with the free carbon dioxide in the sewage and then with the calcium bicarbonate, forming calcium carbonate, which constituted a large part of the flocks which settled and formed the sludge. The excess remained as free calcium hydroxide in the effluent. Considerable time was required for the completion of these reactions, as was shown by adding lime to a sample of the sewage and titrating with standard acid, using phenolphthalein and methyl orange as indicators.

Not only does the reaction seem to be slow but the liquid seems for a time to be supersaturated with calcium carbonate.

Tests were made with no lime at all and a considerable number of proportions up to an excess of nearly 200 parts per million of calcium oxide. When no lime was used and electrolysis only, very little purification of the sewage resulted, as shown by bacteria count and clarification and flocculation. Table III gives the re-

TABLE III

ANALYSIS OF RAW SEWAGE AND SEWAGE PURIFIED BY ELECTROLYTIC PROCESS

ELECTRICAL DATA

Number of electrolyzing elements in series, 31; amperes, 32; volts, 102

CHEMICAL ANALYSIS (Results given in Parts per Million)

	Sample *A*.	Sample *B*.
Temp., degrees C	11	11¼
Nitrogen as		
Nitrites	0.00	1.1
Nitrates	0.06	0.44
Free ammonia	26	22.4
Total organic nitrogen	26	14.4
Oxygen dissolved	2.82	3.5
Per cent of saturation	25.45	31.75
Consumed	74	48
Turbidity	55	35
Color	50	35
Chlorine	64	54
Carbon dioxide	25.0	0
Calcium dioxide	0	0
Alkalinity	291.6	314
BACTERIOLOGICAL EXAMINATION		
Bacteria per c.c.		
Agar	584,000	272,000
Gelatine	1,100,000	846,000
Acid-forming bacteria	55,000	45,000
B. Coli	1–100+	1–10+

sult of electrolysis of the sewage with a very small amount of lime, as indicated by the alkalinity and absence of calcium oxide. The small amount of nitrates and oxygen consumed and large amount of organic nitrogen and oxygen consumed indicate only slight purification, which is also shown by the high bacteria count.

On the same day using the same sewage a test was made in which the excess lime was forty-three parts per million. Very much better chemical and bacterial purification was obtained, as indicated by Table IV.

TABLE IV

ELECTRICAL DATA

Number of Electrolyzing Elements in Series, 38; Amperes, 27; Volts, 125

CHEMICAL ANALYSIS (Results Given in Parts per Million)

	Sample *A*.	Sample *B*.
Temp., degrees C.	11	11¾
Nitrogen as		
Nitrites	0.00	0.24
Nitrates	0.06	4.4
Free ammonia	26	20.0
Total organic nitrogen	26	10.0
Oxygen dissolved	2.82	4.6
Per cent of saturation	25.45	37.90
Consumed	74	55
Turbidity	55	17
Color	50	35
Chlorine	64	75
Carbon dioxide	25.0	0
Calcium oxide	0	43.1
Alkalinity	291.6	101.0
BACTERIOLOGICAL EXAMINATION		
Bacteria per c.c.		
Agar	584,000	6,010
Gelatine	1,100,000	140,000
Acid-forming bacteria	55,000	2,000
B. Coli	1–100+	1–1 + 1–10+

A still higher degree of purity was obtained by using an excess of lime equal to 236 parts per million, as shown by Table V.

This high purity was obtained in spite of the fact that the amount of current used was equivalent to only 1.448 c.c. of anodic oxygen per liter.

TABLE V

ELECTRICAL DATA

Mean rate of sewage flow, gals. per day	760,000
Electrolyzing elements in series	38
D. C. average volts	105
D. C. average amperes	22
Anodic oxygen (theoretical) gramme, per liter	0.00208
Anodic oxygen (theoretical) c.c., per liter	1.448

CHEMICAL ANALYSIS (Results Given in Parts per Million)

	Sample *A*.	Sample *B*.	Sample *C*.
Temp., degrees C.	13	13.5	13.3
Nitrogen as			
Nitrites	0	0.04	0.10
Nitrates	0	2.4	3.6
Free ammonia	26	20	12.0
Total organic nitrogen	14	5.6	0.0
Oxygen dissolved	0.4	2.46	6.11
Per cent of saturation	3.73	23.49	68.01
Consumed	34	20	8
Turbidity	55	2	3
Color	70	25	15
Chlorine	65.5	122	80
Carbon dioxide	24.8	0	0
Calcium oxide	0	236	162
Alkalinity	277.8	.....	.....
Calcium carbonate	.....	239	96

BACTERIOLOGICAL ANALYSIS

Bacteria per c.c.			
Agar	160,000	0	5
Gelatine	1,000,000	0	170
B. Coli	1–1000+	1–10–	1–1–

The effect of the electric current in increasing flocculation and purification of the sewage is strikingly shown in the following experiment.

At the time of starting the experiment the machine was running normally and had been so for several days, current, lime and agitation being employed. The effluent was clear and excellent in every respect. The lime was added at the far or outlet end of the machine.

Sewage flow, 755,000 gals. per day.
Current, 40 amp., 120 volts.

About 1000 lb. of hydrated lime (72.87 per cent calcium oxide) was used per day. This is equivalent to 965 lb. of lime per million gallons, or 9 grains of lime per gallon.

Under these normal conditions the appearance of the liquid in the flume was good, with large flocks, which settled rapidly in the Imhoff tube, leaving a clear liquid above. The Imhoff reading was 20 c.c. (All Imhoff tube readings were made after ten minutes' sedimentation.) The final effluent was nearly water-like in appearance, odorless and there was no odor in the tankhouse or plant generally.

1.50 p. m.—The current was cut off, and the agitation by means of the paddles stopped. The flow of milk of lime into the sewage at the outlet end of the machine was continued.

1.55 p. m.—The liquid in the flume had become very noticeably darker, with much smaller flocks.

2 p. m.—The liquid in the flume was decidedly dark, the flocks small. Imhoff tube reading, 3 c.c.

2.02 p. m.—The current was turned on again, other conditions remaining the same.

2.07 p. m.—The liquid in the flume was lighter and the flock better.

2.12 p. m.—The liquid in the flume same as at 2.07 p. m. A half gallon was lighter in color than a similar sample at 2. Imhoff tube reading, 10 c.c.

2.17 p. m.—The point of lime feed was changed, so as to allow the lime to be admitted at the suction end of the pump, thereby being mixed with the sewage which then passed through the machine. The current was turned off, and there was no agitation by means of the paddles.

2.22 p. m.—The liquid in the flume was darker, and the flocks smaller.

2.31 p. m.—The liquid in the flume was still dark, the flocks small and poor. In the Imhoff tube, the flocks appeared small and poor. Imhoff tube reading 0.75 c.c.

2.32 p. m.—The electrolyzing current was again turned on and agitation by means of the paddles started. The lime continued to be added through the pump.

2.42 p. m.—Color dark in the flume, but flocculation was better.

2.46 p. m.—Imhoff tube reading, 16 c.c., but the sediment was dark in color,

2.47 p. m.—The electrolyzing paddles and current continued in operation but the lime was introduced at the outlet end of the machine. This reproduced the conditions found at 1.30 p. m.

2.52 p. m.—The liquid in the flume became lighter, with a heavy flock, quickly settling. The deposit in the Imhoff tube was heavy, and settled rapidly.

This experiment, together with the one previously made, showed that electrolyzation of the sewage serves to produce a lighter colored effluent, and materially increases the amount of flocculation and precipitation of the suspended matter in the sewage, probably because the current tends to agglutinate the colloidal particles.

The chemical analyses of the effluent show that when the current and lime are both used the effluent is more free from nitrogenous organic matter, 60 per cent of the total organic nitrogen being removed; whereas when the current is not used only 11 per cent of the nitrogenous organic matter is removed and the bacteria multiply in the effluent, probably because of the greater abundance of food.

In order to secure information as to the effect of lime only on the Elmhurst sewage, a number of experiments were carried out in which conditions were identical with the electrolytic treatment except the electrolyzation. Table VI gives the average of these results.

TABLE VI

AVERAGE OF THE ANALYSES OF RAW AND PURIFIED SEWAGE WITH LIME ONLY, WITHOUT ELECTROLYZATION

	Sample *A*.	Sample *B*.	Sample *C*.
Nitrogen as			
Nitrites	.....	0	0.32
Nitrates	.....	0.02	3.6
Free ammonia	22	15.8	10.0
Total organic nitrogen	3.6	3.4	3.2
Oxygen dissolved	2.92	3.78	4.80
Per cent of saturation	27.75	36.25	46.07
Consumed	.....	23.7	21.6
Turbidity	50	33	10
Color	.....	45	14
Carbone dioxide	24.62	0	0
Calcium oxide	0	19.6	9.52
Alkalinity	271.8	299.6	112.1
Calcium carbonate	0	274.2	86.61
Total solids	.....	.....	134
Bacteria per c.c.			
Agar	187,000	54,120	5430

It will be noted on reference to the results given in Table VI that the amount of nitrates in sample B is very small and differs in this respect from the corresponding average in the electrolytic treatment (Table I). In sample C (Table VI), however, the amount of nitrates is 3.6, which is very nearly equal to the corresponding average in Table I.

The organic nitrogen decreases from 3.6 to 3.4, which is a reduction of only 6 per cent compared with 40 per cent in the table of electrolytic treatment (Table I). Between B and C there is a further decrease of only 6 per cent compared with 20 per cent in the table of electrolytic treatment. This indicates an important difference between these methods of treatment and shows that the removal of organic nitrogen is comparatively slight in the case of treatment with lime alone.

The total increase in the amount of dissolved oxygen between samples A and C is 18.32 per cent as compared with 24.49 in the case of the electrolytic treatment. The decrease in bacteria count between A and C is 9.7 per cent as compared with decreases of 84 and 99.83 per cent respectively in the case of the electrolytic treatment.

The most striking evidence of the very marked purifying effect of the treatment with lime and electrolyzation is obtained by noting the change in bacteria content on allowing samples to stand for one or more days. These results are given in Table II.

TABLE VII

STABILITY OF SEWAGE AND EFFLUENT WHEN USING LIME ONLY

Represented by the Number of Bacteria per c.c. Incubated on Agar

A	*B*	*C*	*D*
	At time of taking sample		
140,000	51,000		
	After standing 8 days		
120,000	77,000		
	At time of taking sample		
		10,000	
	After standing 3 days		
		1,540,000	
	At time of taking sample		
124,000		10,000	7,400
	After standing 1 day		
1,860,000		4,032,000	750,000
	After standing 2 days		
520,000		2,670,000	591,000
	After standing 3 days		
820,000		338,000	105,000

It will be noticed that the bacteria increase very rapidly after treatment with lime only Table (VII). In this respect there is a very striking difference when samples which have been subjected to electrolysis and lime are allowed to stand. In this case there is a very marked decrease in the already low bacteria count. An exception to this condition is sometimes found in sample B which has not passed through the sedimentation tank.

The difference between the two processes is also very noticeable on an inspection of sewage disposal plants operated by the two methods. At plants using lime only the effluent is dark colored, quite high in bacteria and far from pure. Both effluent and sludge produce considerable odor so that the disposal works are a nuisance to nearby neighbors, while the effluent pollutes streams into which it is discharged.

On the other hand the Elmhurst plant during the time it has been operating on 750,000 gal. of sewage daily has been entirely free from unpleasant odor, the effluent being clear and free from color and could be discharged into any stream without causing any pollution whatever.

It is common, when discussing electrolytic processes for sewage treatment, to speak of the liberation of chlorine, or the formation of a hypochlorite by the action of the electric current upon the common salt present in the sewage, and then to credit such substances with much of the beneficial action claimed for the process. Careful chemical examination made at various times of the effluent of the electrolytic machine at Elmhurst failed to give any reaction whatever for free chlorine or hypochlorites. The conclusion seems warranted that neither of these substances is present in the sewage electrolyzed by the process.

In order to confirm this conclusion, a study was made of the effect of adding bleaching powder to sewage. A visit was first made to Providence, R. I., where lime and bleaching powder have been used for a great many years in the treatment of the municipal sewage. At the Providence plant 144 lb. of bleaching powder and 400 lb. of lime are used per million gallons of sewage treated. The amount of bleaching powder added is 17.3 parts per million, the available chlorine being 5.7 parts per million. This is equivalent to 1.3 mg. of oxygen per liter, which is about the amount of anodic oxygen produced by the electric current in the Landreth machine. At Providence the treated sewage is allowed to settle in sedimentation tanks.

The effluent as discharged into the river contains from 20 to 50 per cent of dissolved oxygen. The dissolved oxygen in the river is generally zero. Sixty-five per cent of the total bacteria were removed, as counted on litmus agar, incubated at $37\frac{1}{2}$ deg. The B. Coli removed amounted to 97 per cent. The effluent is putrescent and quite impure, but the use of the process is justified by the polluted condition of the river, so that the requirements for purity are very low. The statement was made that if it should become necessary to secure a higher state of purity, a more efficient process of sewage disposal than the one now in use must be installed.

Laboratory tests were made with Elmhurst sewage. Bleaching powder and lime were added in the proportions used at Providence, namely, 144 lb. of the former and 400 lb. of the latter. The odor of hypochlorites was very noticeable and persisted for about 24 hr. No odor of this kind had ever been detected on the effluent at Elmhurst. The sewage also remained turbid and did not settle clear even after several days' standing.

The bacteria count was reduced about 97 per cent, but on standing 21 hr. the bacteria count had risen and was higher than that of the raw sewage. The odor of chlorine had also disappeared, showing that the bleaching powder prevented the growth of bacteria but did not remove the organic matter and produce a stable effluent. The results are given in Table VIII.

TABLE VIII

BACTERIA PER C.C. IN RAW SEWAGE AND SEWAGE TREATED WITH LIME AND BLEACHING POWDER

Bleaching Powder Added, 144 Lb. Per Million Gal. Lime Added, 400 Lb. Per Million Gal.

	Raw Sewage.	Treated Sewage.	Odor.
After standing 1 hour			
Agar	62,000	1,830	Chlorine
Gelatine	520,000	22,000	
After standing 21 hours			
Agar	.....	907,000	Quite putrid
Gelatine	.....	2,430,000	
After standing 3 days			
Agar	.....	1,800,000	Very putrid
Gelatine	.....	2,000,000	

Another test was made in which twice as much lime and bleaching powder was added as used at Providence. This would give chlorine equivalent to about 2.6 mg. of anodic oxygen per liter, which, with the amount of lime used, would give a very clear and stable effluent by the Landreth electrolytic process. In this experiment the chlorine odor persisted for 24 hr., the bacteria count was very low on the second day but after standing for three days, the bacteria count on agar was 5,550,000 and the liquid had a putrid odor. The results are given in Table IX.

TABLE IX

BACTERIA PER C.C. IN RAW SEWAGE AND SEWAGE TREATED WITH LIME AND BLEACHING POWDER

Bleaching Powder Added, 288 Lb. Per Million Gal. Lime Added, 800 Lb. Per Million Gal.

	Raw Sewage.	Treated Sewage.	Odor.
After standing 1 hour			
Agar	62,000	200	Chlorine
Gelatine	520,000	4,200	
After standing 24 hours			
Agar	.....	200	Slight chlorine
Gelatine	.....	160	
After standing 3 days			
Agar	.....	5,500,000	Putrid
Gelatine	Plates entirely liquefied		

In another test the untreated sewage as well as the treated sewage was allowed to stand and was plated. After five days the bacteria count was 4,460,000 in the sewage treated with bleaching powder. The results are given in Table X.

It is apparent from these results that bleaching powder has a very marked destructive action on bacteria, but that there is very little action on the dissolved organic matter. It is, no doubt, very effective in purifying a contaminated water, but is not a suitable reagent for the oxidation of the large amount of organic matter present in a sewage so as to produce a stable effluent.

The sludge produced at Elmhurst amounted to about 1500 lb. of dried material per million gallons of sewage treated. The moist press-cake contained about 69 per cent of water. It also contained

about 0.59 ,per cent ammonia, equal to 3.7 per cent proteid and 0.54 per cent calcium phosphate, the remainder being mostly calcium carbonate. While moist, the press-cake has a slight odor of ammonia, which becomes more intense if the sludge is kept in a closed vessel. Putrescibility tests showed it to be stable for more than four days. When allowed to dry, it becomes entirely odorless. A number of methods of disposal of this sludge seem to be feasible. It can be used as a filler on low ground, as it will not produce a nuisance. If used in this manner, filter pressing would be unnecessary if vacant ground near the plant is available, as the liquid sludge could be pumped out. The sludge would also find some use as a fertilizer. It could also be burned so as to recover the lime.

TABLE X

BACTERIA PER C.C. IN RAW SEWAGE AND SEWAGE TREATED WITH LIME AND BLEACHING POWDER

Bleaching Powder Added, 235 Lb. of 23 Per Cent Chlorine Per Million Gallons, Which is Equivalent to 63 Lb. of Chlorine Per Million Gallons or 6.5 Parts Chlorine Per Million Gallons. Lime Added, 1079 Lb. Calcium Oxide Per Million Gallons.

	Raw Sewage.	Treated Sewage.
After standing 3 hours		
Agar	580,000	130
B. Coli	.....	0
After standing 24 hours		
Agar	.....	230
B. Coli	.....	0
After standing 48 hours		
Agar	300,000	50
B. Coli	.....	0
After standing 3 days		
Agar	610,000	40
After standing 4 days		
Agar	620,000	.....
After standing 5 days		
Agar	.....	4,460,000
B. Coli	.....	0

Cost of Operation. A careful study was made of the cost of operation of this process of sewage disposal. The actual cost of operation of the Elmhurst plant cannot be taken as the no mal operating cost of a plant of this kind because the plant was designed and built for an entirely different process and because during the period of the test it was not continuously operated on a normal basis. The operating cost will include the following items: electric current and power, lime, labor, maintenance supplies, etc., and sludge disposal.

Electric Current and Power. From the study made of the process a fairly accurate estimate may be made of the minimum amount of electric energy required for the electrolyzation of a million gallons of sewage, and this was found to be 85 kw.-hr. The cost of electric current varies greatly in different localities. At 2 cents this item would be $1.70 per million gallons.

Electric energy was also used to rotate the paddles and produce agitation in the machine. This required 60 kw.-hr. per million gallons, and at 2 cents would be $1.20.

A small electric motor was used to operate the agitator in the lime vat and consumed 16 kw.-hr., which at 2 cents would be $0.32.

Lime. It was possible to make a very close estimate of the amount of lime required, which was about 950 lb. of calcium oxide or approximately $\frac{1}{2}$ ton of commercial lime. Under favorable conditions lime can be obtained in carload lots at about $6 per ton, making this item of cost $3 per million gallons.

Labor and Supervision. It has been very difficult to estimate the cost of labor and supervision for a plant of this kind from the experience at the Elmhurst plant. This element of cost will decrease very rapidly with the size of the plant and will also vary with the method of sludge removal employed. For a 10,000,000-gal. plant $3 per million gallons would seem reasonable.

Maintenance and Supplies. The principal item of expense under this heading will be the renewal of the iron electrode plates. This and other items would be covered by an allowance of $1 per million gallons.

Sludge Disposal. The cost of sludge disposal would vary with local conditions and especially with the methods of disposal which may be utilized. The simplest and cheapest method of disposal consists in pumping the liquid sludge on the land adjoining the plant which must be filled in. The cost of pumping the sludge

TABLE XI

ESTIMATED COST OF SEWAGE DISPOSAL BY ELECTROLYTIC PROCESS FOR A TEN-MILLION-GALLON PLANT

Lime, 5 tons at $6.00 per ton	$30.00
Electricity for electrolyzation at 2c	17.00
Electricity for agitation at 2c	14.20
Labor and supervision	30.00
Maintenance and supplies	10.00
Sludge disposal	25.00
	$126.20
Cost per million gallons	$12.62

obtained from a million gallons of sewage is very small. If the sludge is used for fertilizer it must be filter-pressed. This will cost about $2.50 per million gallons of sewage. In a farming section the filter-pressed sludge will be removed by the farmers. Where this is not feasible the sludge must be disposed of by removal and dumping on waste land or at sea. Where this is necessary the cost may be considered $2.50 per million gallons of sewage.

ADVANTAGES OF THE METHOD. The advantages of the method may be briefly stated as follows:

(*a*) The effluent is of a very high degree of purity and may be discharged into any water course without creating any nuisance whatever or injury to fish or oysters.

(b) No odor or other nuisance is produced by the plant, so that it may be located at any sewer outlet or other convenient point.

(*c*) The amount of space required for the plant is very small. This very much reduces the cost of the necessary site and gives a much more general choice of location.

(*d*) On account of the freedom from nuisance and small space required, plants may be located at convenient points and the construction of costly trunk sewers obviated.

(c) The initial cost of installation is low as compared with other processes.

COSTS AS APPLIED TO PROFESSIONAL BUSINESSES

By RALPH A. GOULD

Read at the San Francisco Meeting, August 26, 1914

In the conduct of all modern manufacturing enterprises we hear a great deal about efficiency. Chemical engineers and chemists need no arguments to convince them of the value of efficiency as it is brought about through control of conditions governing manufacturing processes. Business efficiency contemplates not only efficient manufacturing but efficient selling and accounting. Manufacturing industries and mercantile businesses are instructed in over abundance in the matter of system. There seems, however, to be a real dearth of information as to comparative efficiency and system in the conduct of professional businesses.

It is easy to understand why the professions are seldom or never discussed from the point of view of their efficient conduct. The professional man carries his capital under his hat; his outlay for equipment is but a small amount of his capital when the latter is considered from the point of view of earning capacity. The consulting engineer who has a business of $100,000 a year probably has no equipment other than an office, a library and a staff of office assistants. The chemical engineer must necessarily have a laboratory equipment but even its cost is but a small item of his working capital. We are all, theoretically at least, reasonably modest in discussing with our fellows what we believe our earning capacity to be, in other words our capitalization. There has existed in the past and even in these enlightened days there are evidences of much professional jealousy between practicing members of the same profession, though the gradual breaking down of the bars of secrecy and the interchange of technical ideas through the professional societies has placed all of the professions upon a sounder and a broader business basis.

Arguments on the ethics of professional fees and their size might be advanced at this time but it would seem that such would ultimately show that the general trend of twentieth century professional

business is towards uniform fees to all clients and a most commendable disposition to do away with the black mysteries of former days in connection with the professions.

The professional man sells service directed by systematic training in contrast to the unskilled workman who sells simply service and in further contrast to the manufacturer or merchant who sells material. All are entitled to remuneration as a result of their labor: the first and the last are, furthermore, entitled to profit because of their invested capital, in the one case training, in the other money. The profits of the professional man are mainly dependent upon his ethics and his ability at his profession, while with the manufacturer or merchant profits are largely the result of the laws of supply and demand.

As a contribution to the general information on the subject of professional businesses and in line with the increasing tendency to discard the mysterious, why cannot the professional man discuss his efficiency factors with as much benefit to himself and colleagues as have the manufacturers and the merchants? It is my belief that he can.

Professional men have from time immemorable been notorious as being poor business men. The practicing engineer who effects economies where wastes have been the rule is certainly a good business man for he has conserved resources. The ideal business man is just that:—one who conserves and extends his resources. The difference between the professional man and the business man is mainly one of loyalty to an ideal developed and fixed by training. Few business men are actuated in their work, as are large numbers of professional men, by associations concerned with an extended preliminary training, which training is valued for itself as well as for what it will produce of this world's goods; and few professional men realize the experimental value of the obstacles encountered by the business man in the conduct of his affairs.

We can find monographs, pamphlets, magazines and books dealing with the manufacturing costs of nearly every thing that is manufactured; but we seldom, if ever, hear what the manufacturing costs are of any professional business, how they are figured, or how they are or should be applied for a study of the condition of the business.

In the hope that this paper, even though elemental, will bring out some discussion of the subject the writer feels that some of the ex-

periences encountered in a rather short period of time in conducting, with my associate, a chemical engineering business, may not prove uninteresting.

At the risk of being considered somewhat too personal, it may be stated that the business referred to was launched during the latter part of 1912. We had a strong desire to apply a cost system to our business which would give us some detailed information relative to success or failure in the annexing of profits.

Proceeding along reasonably well thought out lines we divided our possible clients into three classes; 1st, "contract clients" or those from whom a yearly retainer is received; 2nd, "regular clients" or those from whom specific commissions are obtained, and 3rd, "overhead clients" a classification designed to cover investigations we desired to undertake at our own expense or at the expense of a client where the profitable remuneration is contingent upon the success of the investigation. Our work is confined almost exclusively to consultation and the application of chemistry to manufacturing processes and manufactured products either through the establishment and maintenance of chemical control of processes, the improvement of processes, utilization of wastes or origination of new products and to such engineering problems as present themselves in these connections. We maintain suitable laboratories for the conduct of necessary research and investigations and for making analyses of raw and finished materials. We do not, however, do a transient analytical business.

The first element in the production of an accurate cost record is that of expended time. Every one connected with the business in question from boss to boy fills out a time slip at the end of each day. This time slip shows as accurately as possible, without the expenditure of any great amount of effort, what particular work engaged the person during the day, the client for whom it was performed and the amount of time spent at the work. Thus:

NAME: RICHARD THOMAS. Date 4-1-15.

Client	Work	Hours
Phoenix Ink Co	Analysis of Pigments	4
Jason Milling Co	Exp. on gluten extraction	3
Willson Rubber Co	Recovery of wastes work	1
		8

In the case of employees, the hours accounted for on the daily time slips must equal eight or more, whether they are spent at work or otherwise. Our employees are paid by the month, so that, irrespective of the number of hours worked the cost is the same.

In the case of members of the firm, "unexpended time" and time spent at work other than specifically remunerative work is accounted for each day. A considerable amount of time is necessarily spent at management, supervision, etc., which must be classed as "overhead work." Each member of the firm draws a stipulated salary (when he can get it) which must be earned by the expenditure of not less than 250 hours per month or an accounting for such an amount of time. Under such a scheme, of course, the salary of the member of the firm who puts in time in excess of 250 hours per month presents the anomaly of a minimum remuneration for a maximum of work, but in making up charges to clients, as will be shown later, it is necessary that all time spent be accounted for on the time slips. "Unexpended time" and "overhead time" of members of the firm are counted as overhead costs. If, however, a member of the firm actually spends 250 hours per month at remunerative work, such "unexpended" and "overhead" time as is accounted for on the slips is not calculated as overhead.

The filling out of these time slips was very onerous at first, and even now is considerable of a bother, but we feel that the information gained in the end more than compensates for such annoyance.

These daily time slips are regularly posted by a clerk into a " cost sheet" which is made out in the name of each client or commission. A cost sheet is carried through each month made out to "overhead" as a client, to enable us to check the actual time spent at overhead work, whether it enters the overhead costs or not. The extension of the cost sheet items on the completion of a specific commission or at the end of the month in the case of contract clients is a simple matter.

Our charges are made up as follows: First, retainer and contract fees; second, charges are made at a fixed per diem for the time of a member of the firm spent at work which cannot be done by assistants; (the day is eight hours in San Francisco and of indeterminate length in the field, that is, a day's field work may require more than eight hours but the charge is always for eight hours); third, the time of employees is charged at net cost to us plus a fixed

overhead charge. There are, of course, expense charges at times which are provided for in the cost sheet.

When we began our business the question of overhead charges for employees' time was a "puzzler." We had no disposition to make a profit on such charge, neither did we wish to sustain a loss. Inasmuch as we were not doing a business in which a fixed result, for example an analysis, is the basis of charge, we had to charge for time. In our previous experience of some fifteen years each, we had obtained no data which would indicate with any exactness how much it actually costs to conduct a professional business. The best we could do was to fix this overhead charge on a guess. We guessed that a 20 per cent overhead charge on the time of the employees would be about the probable cost of doing business, and up to 1915 we made our charge on that basis. As will be shown later, our guess was wide of the mark.

Having extended the time costs and charges, consideration is next given to "expense" specifically attached to the work of each client. When especial equipment or supplies are needed to do a piece of work, the expense is "billed to the client" or "not billed," as the circumstances indicate, or in accordance with such arrangements as have been previously made with the client relative to expense of an extraordinary nature. Expense "not billed" is charged on the cost sheets against the work. General expenditures for supplies, rent, gas, light, power, etc., make up part of the overhead costs.

The cost of each client's work, therefore, is made up of firm time, employees' time, "not billed" expense and prorated overhead.

In prorating the total overhead costs two methods, at least, are applicable—possibly more are available. One is to prorate the total overhead costs on a basis of charges made. Owing, however, to the fact that contract work, because of its routine character, can be done more cheaply than irregular commissions, such a basis of prorating would not be fair, as it would throw a larger burden of overhead on the higher priced irregular commissions which cost but little more than the low priced contract work. The other method is to prorate the overhead on a basis of time spent at remunerative work by both firm members and employees. While this method, as well as the other, has certain disadvantages, it is believed, after a considerable experience with it, that it presents fewer anomalies than the other method would.

The items that go to make up the "overhead" under this basis are:

Time of members of the firm spent at unremunerative work;
Time of technical employees spent at general laboratory work from which all laboratory work profits;
Time of laboratory helpers, clerks and non-technical employees;
Expense for rent, supplies, equipment, gas light, power, etc.

These data are readily assembled and the overhead can be easily prorated on the basis of the time spent for each client at remunerative work. In taking off the monthly statements we would have, as an example of a month of average overhead, something like the following:

Overhead time of members of the firm	$ 56.00
Overhead time of employees (technical)	12.00
Overhead time of employees (non-technical)	165.00
Expense	140.00
Total overhead costs	$373.00

The cost sheet has the following form, and as made out at the end of each month resembles the following half dozen sheets representing hypothetical clients.

CLIENT: A. January 1915. Sheet No. 1

BUSINESS: Process for extracting gluten from barley (RC) in charge of J.D.D. File 207

Time							Expense	
Date	Item	Person	Hours	Cost		Charge	Item	Billed
				Firm	Em-pl'yees			
2	Design Ext. Apparatus..	JDD	3	3.00	....	15.00	Manufacture of Extract-	
4	Design Ext. Apparatus..	JDD	12	12.00	....	40.00	or J. T. B. Co.....	65.00
5	Drafting on Ext, Appts..	RPT	4	....	2.50	3.33		
10	Exp. run with Ext. Appt.	JDD	2	2.00	....	10.00		
..	Exp. run with Ext. Appt.	RPT	8	....	5.00	6.66		
11	Exp. run with Ext. Appt.	RPT	10	....	5.00	6.66		
12	Analyt. work on extracts	RPT	10	....	5.00	6.66		
13	Analyt. work on extracts	RPT	4	....	2.50	3.33		
	Study of analyt. results.	JDD	2	2.00	....	10.00		
				32.00	58.00	237.33		

DETAILS FOR THE MONTH ON TIME SLIPS.

COSTS		CHARGES	
Firm Time	32.00	Retainer	
Employees' Time	58.00	Other Charges	237.33
Expense (not billed)		Total Charges	237.33
Prorata Overhead	44.57	Total Costs	134.57
Total Costs	134.57	Profit	102.86

CLIENT: B. January 1915. Sheet No. 1

BUSINESS: Control of processes. (CC) in charge of CBK. File 756.

Time						
Date	Item	Person	Hours	Cost		Charge
				Firm	Employees	
5	Laboratory work.....	FTR	6	....	3.12	
9	Laboratory work.....	FKP	10	....	4.16	
10	Laboratory work.....	RZM	8	....	4.00	
11	Laboratory work.....	FTP	10	....	4.16	
..	Laboratory work.....	RZM	10	....	4.00	
12	Inspection of Plant.....	CBK	4	4.00		
				20.00	140.00	

DETAILS FOR THE MONTH FROM TIME SLIPS.

COSTS		CHARGES	
Firm Time	20.00	Retainer	300.00
Employees Time	140.00	Other Charges	
Expense (not billed)		Total Charges	300.00
Prorata Overhead	79.26	Total Costs	239.26
Total Costs	239.26	Profit	60.74

CLIENT:
BUSINESS: Utilization of waste rubber.

January 1915. Sheet No. 1
(OC) in charge of C.B.K. File 436.

Time							Expense	
Date	Item	Person	Hours	Cost: Firm	Cost: Empl'yees	Charge	Item	Billed
18	Experimental Digestions	CBK	5	5.00			Machine work on digestion Apparatus J. T. B. Co.	78.40
19	Experimental Digestions	CBK	4	4.00				
20	Experimental Digestions	CBK	12	12.00				
21	Analytical work on ext...	CBK	8	8.00				
..	Analytical work on ext...	RZM	10	....	4.00			
22	Analytical work on ext...	CBK	2	2.00				
..	Analytical work on ext...	RZM	4	....	2.00			
				48.00	6.00			

DETAILS FOR THE MONTH FROM TIME SLIPS.

COSTS		CHARGES	
Firm Time	48.00	Retainer	
Employees' Time	6.00	Other Charges	
Expense (not billed)		Total Charges	
Prorata Overhead	26.75	Total Costs	80.75
Total Costs	80.75	Loss	80.75

CLIENT: D.
BUSINESS: Destructive distillation of wood waste.

January 1915. Sheet No. 1
(RC) in charge of J.D.D. File 586.

Time							Expense	
Date	Item	Person	Hours	Cost: Firm	Cost: Empl'yees	Charge	Item	Not Billed
7	Experimental distils....	JDD	8	8.00	....	40.00	Construction of digestion Tank J. T. B. Co..	36.00
8	Analyt. work on distils...	RPT	10	....	5.00	6.66		
9	Analyt. work on distils...	RPT	8	....	5.00	6.66		
..	Analyt. work on distils...	JDD	4	4.00	....	20.00		
10	Experimental distils....	JDD	12	12.00	....	40.00		
11	Analyt. work on distillate	RPT	11	....	5.00	6.66		
				100.00	42.00	556.00		

DETAILS FOR THE MONTH FROM TIME SLIPS.

COSTS		CHARGES	
Firm Time	100.00	Retainer	
Employees' Time	42.00	Other Charges	556.00
Expense (not billed)	36.00	Total Charges	556.00
Prorata Overhead	70.32	Total Costs	248.32
Total Costs	248.32	Profit	307.68

CLIENT: E. January 1915. Sheet No. 1

BUSINESS: Control of processes. (CC) in charge of J.D.D. File 279

Time

Date	Item	Person	Hours	Cost		Charge
				Firm	Employees	
12	Analytical work.....	RPT	10	....	5.00	
18	Analytical work.....	RPT	8	....	5.00	
22	Analytical work.....	FTP	4	....	2.08	
23	Analytical work.....	RZM	8	....	4.00	
24	Analytical work.....	RPT	8	....	5.00	
					27.00	

DETAILS FOR THE MONTH FROM TIME SLIPS.

COSTS		CHARGES	
Firm Time.....		Retainer.....	100.00
Employees' Time.....	27.00	Other Charges.....	
Expense not (billed).....		Total Charges.....	100.00
Prorata Overhead.....	13.35	Total Costs.....	40.35
Total Costs.....	40.35	Profit.....	59.65

CLIENT: F. January 1915. Sheet No. 1

BUSINESS: Control of Processes. (CC) in charge of J.D.D. File 555

Time

Date	Item	Person	Hours	Cost		Charge
				Firm	Em-pl'yees	
1	At plant installing filters.	JDD	6	6.00		
2	At plant operating filters	JDD	10	10.00		
3	Expt. run on waste recovery.....	JDD	4	4.00		
4	Analyt. work on wastes .	RPT	10	....	5.00	
5	Analyt. work on wastes..	RPT	8	....	5.00	
				146.00	134.00	

Expense

Item	Not Billed
Equipment — Electrolytic precipitation apparatus J. C. Co.....	87.50

DETAILS FOR THE MONTH FROM TIME SLIPS.

COSTS		CHARGES	
Firm Time.....	146.00	Retainer.....	500.00
Employees' Time.....	134.00	Other Charges.....	
Expense (not billed).....	87.50	Total Charges.....	500.00
Prorata Overhead.....	138.75	Total Costs.....	506.25
Total Costs.....	506.25	Loss.....	6.25

The prorated overhead would be as follows:

	Cost of remunerative Work	Percent of Costs	Prorated Overhead
Client A.....	$ 90.00	$ 11.95	$ 44.57
Client B.....	160.00	21.25	79.26
Client C.....	54.00	7.17	26.75
Client D.....	142.00	18.85	70.32
Client E.....	27.00	3.58	13.35
Client F.....	280.00	37.20	138.75
Totals.....	$753.00	$100.00	$373.00

The Earnings and Profit Sheet for the month would have the following form, using the same hypothetical clients:

Client	Costs						Profit	Loss	% P or L
	Total Charges	Time Costs		Expense	Prorated overhead	Total Costs			
		Firm	Employees						
A.	237.33	32.00	58.00	....	44.57	134.57	102.86	...	P 43.61
B.	300.00	20.00	140.00	....	79.26	239.26	60.74	...	P 20.37
C.	.....	48.00	6.00	....	26.75	80.75	....	80.75	L 100.00
D.	556.00	100.00	42.00	36.00	70.32	248.32	307.68	...	P 55.20
E.	100.00	....	27.00	....	13.35	40.35	59.65	...	P 59.65
F.	500.00	146.00	134.00	87.50	138.75	506.25	....	6.25	L 1.23
	1693.33	346.00	407.00	123.50	373.00	1249.50	530.93	87.00	

Loss = 87.00

Net Profit = 443.83
% Net Profit = 26.2%

It is an easy matter to collect the monthly statements of earnings and profits into a semi-annual and an annual statement, and a study of the figures in our own case has been productive of much valuable information as to the origin of the profits and losses from a year's business and the totals of success or failure.

While the data obtained in a two year period cannot of necessity

be of great determinative value, they do point a way and it is hoped that they will serve as a basis of comparison for others and stimulate a wider distribution of information as to costs of conducting a professional business.

It is pretty generally believed that professional men make enormous profits and there is no doubt that in some instances this is so. Large fees for advice, which is given in a few minutes and which is of great value to the one advised, are not common, at least in the scientific professions. The scientific man usually has to do real work for his fees.

The profit from any professional business will, of course, be dependent upon the salary adopted as compensation for the owner of the business. Profits must necessarily be the net amount earned over and above such salary. It is difficult to compare the profits of a professional business with those of a mercantile business because of the item of capital. A business of $1000 a month in which the professional man obtains a salary of $100 would show profits much different from one of the same volume where the owner takes $500 as his monthly salary. A mercantile business which pays 15 per cent net profit is not an unheard of business and there are undoubtedly many which pay more. The question of whether a professional business should pay a larger percentage of profit than a mercantile or manufacturing business is open to argument. The professional man generally considers that it should. This seems to be a logical conclusion, because the professional man puts capital into his business as represented by training which is an intangible asset, but which in reality should be figured as capital; and because the total volume of business which any one man is capable of doing, that is the total earnings, must of necessity be less than the total volume of a business which is founded upon the law of supply and demand, and which moves merchandise. An engineer capable of earning $12,000 a year must put in a good deal of his personal time at actual work, and his assistants are highly trained men; while a mercantile business which does a total business of $24,000 a year can be conducted with much less personal effort on the part of the owner of the business and with less skilled help, consequently at less cost. A net profit of $6000 from each business would be had from 50% and 25% of profit respectively.

With the figures we have adopted for our salaries, which need not be mentioned other than to say the figure is reasonable, our net

profits in 1913 amounted to 31% of the business done, while for 1914 the net profits were 34% of the business done. Inasmuch as our fees are uniform, this means that we succeeded in lowering the cost of doing business 3 points in 69 or 4.35%, to which we are rightly entitled as profit.

Coincident with this increase in net profits there was an increase of 45.5% in our "employees' costs" as between 1913 and 1914. This increase is indicative of either or both of two things; we had increased business which required more employees or we turned over to employees a greater proportion of detail work of importance rather than do it ourselves, and charge the client for personal service, at our fixed per diem charge. As a matter of fact, the figure represents both conditions.

As between the years 1913 and 1914 our "expense" costs were diminished by 50% in the latter year. This, as is plainly shown by the detailed cost segregations, indicates that our equipment was augmented during the first year to such an extent that, even though the additional commissions received required a greater outlay for special equipment than in 1913, the previously augmented equipment reduced the "expense" cost during 1914.

In 1913 our overhead expense constituted 36% of the total costs of doing business while in 1914 there was a reduction of 11% in our overhead, so that it constituted but 32% of our total costs. In this connection it will be noted that the guess we made that 20% overhead would be about the cost of doing business was quite without warrant, the two years average 34% overhead.

Our gross profits for 1914 were 1/6th more than in 1913, and our net losses were increased 36%. The increase in "net losses" is due to our assumption of more "Overhead Clients" which, as we carry them, cover a loss until the investigation or work is successful and becomes remunerative. Some of the net losses represent, of course, actual loss in doing work for clients at fees on which we make a loss. When such loss is made it is "experience" and we aim not to repeat it.

In the final analysis, the figures that we have collected from our system have shown us that it costs us 33 1/3% to do business. They show us the exact status of each client's business; how much we made or lost and exactly where we made or lost it; whether members of the firm are putting in too much time on unprofitable work and whether the connection with an unprofitable client should

be continued on the same basis. They show us the average profit derived from profitable clients and give us valuable figures upon which to base estimates relative to new contracts and overhead clients.

It probably should be remarked in closing that the expense costs of our overhead are the usual rental charges in good sized cities for working, not fancy, laboratories and a reasonably well located office suite. We buy in quantity where we can and think we buy as close as the average, but we buy working apparatus, not frills and furbelows.

THE IMPROVEMENT OF HIGH BOILING PETROLEUM OILS, AND THE MANUFACTURE OF GASOLINE AS A BY-PRODUCT THEREFROM, BY THE ACTION OF ALUMINUM CHLORID

By A. M. McAFEE

Read at the San Francisco Meeting, August 25, 1915

The conversion of high boiling petroleum oils into lower boiling oils of greater commercial value is an old problem, and many solutions of it have been proposed. Formerly, when kerosene was worth more than gasoline, naturally the effort was to increase the yield of kerosene from crude oil; nowadays, gasoline is worth more than kerosene, and naturally the effort is to increase the yield of gasoline. But in principle, gasoline making and kerosene making from high boiling petroleum oils are the same, and most of the proposed methods make both products. With very little variation, most of them will make gas equally well. A careful examination of these methods will show, in nearly all cases, the same principle, namely, what is called cracking,—heating to a sufficient temperature to cause the high boiling oils to become unstable and break down into lower boiling oils. If the heat be intense enough and the time be long enough the product will be gas; less heat and a shorter time will make gasolene, and still less heat and shorter time will make kerosene.

The inventors have rung the permutations on this simple idea; they heat under pressure and they heat under vacuum; they heat in the presence of gases; they heat in the presence of catalysts; they heat in tubes and they heat in boilers, etc., etc. It is safe to say that 99 per cent of the methods which have been proposed for converting high boiling oils into lower boiling oils, "cracking" by heat is involved. Sometimes it is disguised in ornate language; sometimes it lurks behind intricate apparatus, but it is always there.

The difficulty, however, with all these cracking methods is a difficulty in principle. In breaking down the complex, high boiling hydrocarbons into several simpler ones, there is not enough hydro-

gen to saturate these newly formed bodies, and unsaturated hydrocarbons must necessarily result unless hydrogen be added or carbon subtracted. Hydrogen is too expensive and difficult to add, and, though a part of the carbon is readily enough subtracted and deposited, this subtraction and deposition never goes far enough,—although the stillman might not be readily convinced of this. These cracked products are in large part unsaturated, and they are not desirable commercially. They are foul smelling; they are yellow in color and become rapidly more yellow on standing; they deposit large amounts of carbon on ignition in a gas engine; they burn with a smoky flame; they contain resinous bodies which cause gumming in use or on standing, etc., etc. They can, of course, be refined somewhat with sulphuric acid, but there must be too much of the acid used and too much of the oil is lost to permit in practice any thorough treatment with acid.

Aside from the poor quality of the liquid products obtained, the operation of the cracking process is attended with great difficulty where uniform results are desired. There are many variables on which the obtaining of such results depends,—temperature, time, pressure and catalytic action of the walls of the containing vessel. A change in either of these variables makes a change in the products obtained. Using the same apparatus, the same pressure, and consuming the same time, a difference of a comparatively few degrees of temperature in cracking operations makes marked differences in the yield and quality of liquid products.

In most of the cracking processes, pressure is employed. Sixty to one hundred pounds is usual and some have proposed much higher pressures. It is here that the greatest difficulty becomes manifest,—the great danger to the operators and to the plant. There is always a deposition of hard (and flinty hard) coke on the inner walls of the heating element. Some who have had considerable experience in cracking oils have said that the coke is forced into combination with the iron, making it brittle, and thus utterly unable to withstand the high temperature and pressure employed. At any rate, the deposition of the carbon occurs where the element is hottest, causing a local overheating at that point. Under such conditions the tensile strength of the steel becomes an unknown quantity,—as likely as not it yields to the stress without any warning. Oil vapors of a temperature around 650° F. ignite spontaneously when they evolve from a still into the surrounding atmos-

phere. In cracking processes the temperature is 750° to 850° F. and even higher, hence the manifest danger of cracking petroleum oils under such pressures.

When I took up the gasoline problem, some 2½ years ago, I dismissed from consideration the idea of cracking oils. Up to this time, or since the Friedel and Crafts British patent, No. 4769 of 1877, there had been some degree of mild interest shown as regards the effect which aluminum chlorid might have on petroleum oils, but no positive results had followed from this interest. It appeared to me that this reaction might have far more significance than was then apparent; I trust this paper may in a measure exemplify its significance.

I have found that with proper control of the vapors leaving the distilling system and entering the final condenser, and with sufficient time given the aluminum chlorid, high boiling oils can be completely broken down into lower boiling oils, and no matter how unsaturated the high boiling hydrocarbons may be, the low boiling oils produced therefrom are sweet smelling, water white and saturated. The reaction gives little gas and only about the right amount of carbon to allow production of saturated products. The carbon is deposited not in the form of a hard baked-on coke, but as a granular, coky mass, easily removed from the still.

But there are other products than gasoline that can be made from petroleum which are commercially worth while, although in our efforts to increase the supply of gasoline we have apparently forgotten this fact. If the market value of the various products which can be obtained from crude petroleum be plotted, it will be found that there is a peak at the low boiling end and another at the high boiling end. Gasoline is worth more than kerosene and kerosene is worth more than gas oil, while the products following gas oil, paraffin and lubricating oils, are worth as much or more than the gasoline.

The problem before me, therefore, knowing the reactive power of aluminum chlorid, was to apply it to crude petroleum so that good heavy oils could be obtained while at the same time converting the less valuable portions of the crude into gasoline. The solution of this problem is found in my patent.

In the practical operation of this process, crude petroleum of any kind is first distilled until the naturally occurring gasoline and kerosene, if there be any present, is distilled off. As you are

probably aware, in many of our crude oils and especially some of those from Texas, California and Mexico, there is substantially no gasoline present and very little kerosene. But in any event, the crude is first heated to free it of any moisture which it may contain, since the oil must be perfectly dry before adding the aluminum chlorid.

The next step is to add anhydrous aluminum chlorid to the remaining residual oil, and then bring the mixture to boiling in the still. Boiling is usually around 500° F. and generally remains between 500 and 550° F. during the entire distillation, extending over a period of twenty-four to forty-eight hours. There is no need of employing extra pressure or vacuum or special still; any still with a stirrer in it suffices.

Granted sufficient time for the aluminum chlorid to get in its work, the success or failure of this process depends upon the proper control of the temperature at which the oil vapors are allowed to leave the distilling system to enter the final condenser. Between the still and the final condenser are placed two air cooled condensers connected in series, which separate the low boiling oils from the high boiling oils, returning the latter together with any volatilized aluminum chlorid to the still. For a 1000 barrel still the air condensers which we are now using are drums of oval cross-section, 3′×6′×6′ high. In addition to the air condensers, a 3-foot dome is attached to the top of the still which serves to return most of the volatilized aluminum chlorid and its compounds. The operation is so controlled that the vapor is kept at the desired temperature as indicated by a thermometer placed in the vapor line at the point of exit of vapor into the final or water cooled condenser. The temperature at this point should not exceed 350° F., otherwise not only will heavy oils distill over, but the aluminum chlorid (or its compounds with hydrocarbons) will enter the condenser and clog it up. Under the first named condition, the distillate obtained will be a mixture of gasoline, solvent oil and kerosene which are afterwards separated by fractional distillation. These products are all water white, sweet smelling, saturated and need no refining with sulphuric acid. In practice, no treatment is given them, except a washing with alkali, followed with water, to remove hydrogen sulphide. With proper back-trapping of high boiling oils into the still from the air cooled condensers and a temperature of 300° F. in the vapor line, the distil-

late obtained will be gasoline alone, which is ready for the market when washed with an alkaline solution.

I have spoken of the time which should be given the aluminum chlorid for the accomplishment of the desired results. It is a mistake to assume that with a given amount of aluminum chlorid and boiling it up with oil, the desired results will be obtained. That is far from the truth. I do not wish to impose upon your patience by dismissing consideration of the mechanism of this reaction by simply saying it is catalytic. I am fairly well satisfied that it is one of association or combination in the liquid phase and dissociation in the vapor phase. It is well known that aluminum chlorid exists in the solid and liquid states as Al_2Cl_6 and in the vapor state as $AlCl_3$. It is also well known with what avidity aluminum chlorid in the solid or liquid state will combine with other salts to form double salts. The most common of these double salts is that of aluminum and sodium chlorid which, at one time, as you know, was the source of metallic aluminum (Castner process). Aluminum chlorid probably combines with these high boiling, complex hydrocarbons in much the same way as it combines with sodium chlorid, and when the boiling temperature is reached these double compounds become unstable, and dissociate into lower boiling hydrocarbons, which, under the temperature control imposed in the vapor line, leave the distilling system as fast as produced; Al_2Cl_6 is again formed and is capable of combining further with other high boiling hydrocarbons remaining in the still, and free carbon is formed simultaneously. This view of the reaction here involved is confirmed, I believe, by the operating conditions mentioned heretofore as necessary for obtaining the desired results.

While the operation, using crude oil as the starting material, can be carried on to produce larger or smaller quantities of gasoline, in practice it is carried on so as to convert the gas oil fraction into low boiling hydrocarbons and leave most of the high boiling hydrocarbons, that is, the paraffins and lubricating oils. Accordingly, the operation is interrupted after a portion of the crude has been converted into low boiling products, and the high boiling oil remaining in the still is pumped off while hot and on cooling is worked up into the usual paraffin and lubricating products. The aluminum chlorid remains in the still enmeshed in a mass of coke, and the methods of its recovery are found in my patents which, if I may, I will refer to further on in this paper.

As illustrative of the action of aluminum chlorid on high boiling petroleum oils I shall give below results obtained on typical crudes. For the sake of convenience, the distillate obtained by distilling the crude before the addition of aluminum chlorid will be termed "primary distillate", the oil remaining in the still being termed "primary residual oil"; the distillate obtained by distilling the primary residual oil with aluminum chlorid will be termed "secondary distillate" and the oil remaining in the still, "secondary residual oil." Fahrenheit temperature and Baumé gravity are used throughout. The distillation tests were made on 100-cc. samples contained in standard Engler flasks connected to a 22-inch Liebig condenser. All flash points noted are in open cup tester. Viscosities noted are on the Saybolt Universal Viscosimeter at 100° F. W.W. and S.W. are abbreviations for water white and standard white, respectively.

Texas crude of 20.8 gravity was distilled until free from moisture and until the naturally occurring gasoline and kerosene had been distilled over.

Yield.	Per Cent Crude.
Primary distillate	7.14
Primary residual oil	91.26
Loss	1.60
Total	100.00

Tests on Primary Distillate

Gravity	36
Bromine No.	5.46

Distillation over	260° F.
10%	320
20%	344
30%	368
40%	386
50%	400
60%	442
70%	468
80%	490
90%	505
95%	520

The primary distillate yielded on fractional distillation the following products:

	Per Cent Crude.	Gravity.	Color.	Per Cent Sulphur.	Bromine Number.
Gasoline	0.303	58.0	W.W.	0.065	4.8
Gas naphtha	0.180	51.0	S.W.	0.103	3.1
W.W. kerosene	1.260	41.6	W.W.	0.071	
S.W. kerosene	1.530	40.9	W.W.	0.133	
Gas oil	3.791	31.2	.....	0.386	
Loss	0.076				
Total	7.140				

TESTS ON PRIMARY RESIDUAL OIL

Gravity	19.8
Viscosity	302
Distillation over	480° F.
10%	530
20%	566
30%	600
40%	656
50%	680

To the primary residual oil was added 7½ per cent by weight of anhydrous aluminum chlorid, and the mixture brought to boiling. The following observations were made during the course of the run:

Time.	Temp. of Still.	Temp. of Vapor Line.	Distillate Per Cent Charge.	Gravity.	Distillation Test.			
					Over Deg F.	Per Cent Below 350° F.	Per Cent Below 450° F.	Dry Point.
1 P.M.	454	268	Showed up					
1:30	479	290	2.86	55.9	110	68	80	490
1:45	488	300	2.86	55.2	110	69	84	490
2:15	495	302	2.86	54.4	110	66	80	490
2:45	504	290	2.86	54.1	110	66	81	490
3:15	508	290	2.86	53.5	110	65	80	490
4:15	518	340	2.86	53.7	110	65	80	490
4:45	523	340	2.86	53.7	110	65	83	490
6:00	525	340	2.86	53.5	105	60	82	490
7:00	530	344	2.86	53.3	100	58	81	490
8:30	530	340	2.86	53.5	100	58	81	490
10:30	542	340	2.86	53.2	100	60	83	490
1 A.M.	547	320	2.86	52.6	100	60	83	490
4:00	547	300	2.86	52.4	100	60	83	490
6:30	552	290	2.86	52.8	100	58	83	495
10:00	551	305	2.86	50.6	100	58	83	500
1 P.M.	557	302	8.57	49.7	100	55	85	510
	From Back Trap		1.39					

The operation was stopped at the end of twenty-four hours.

Yield.	Per Cent Charge.	Per Cent Crude.
Secondary distillate	52.86	48.24
Secondary residual oil	31.14	28.42
Loss (gas and coke)	16.00	14.60
Total	100.00	91.26

Tests on Secondary Distillate

Gravity	51.1
Distillation over	100° F.
10%	174
20%	228
30%	265
40%	294
50%	324
60%	357
70%	388
80%	428
90%	475
95%	500

The secondary distillate on fractional distillation yielded the following products:

	Per Cent Charge.	Per Cent Crude.
Gasoline	38.18	17.45
Gas naphtha	26.62	12.85
W.W. kerosene	2.65	1.28
S.W. kerosene	9.53	4.59
Solar oil	21.80	10.52
Loss	3.22	1.55
Total	100.00	48.24

The tests on the gasoline and the gas naphtha are as follows:

	Gasoline.	Gas Naphtha.
Color	W.W.	S.W.
Odor	Sweet	Sweet
Bromine No.	4.2	3.2
Dr. test	O.K.	O.K.
Heat test	4	3
Sulphur	0.056%	0.054%
Gravity	64.5	50.2

	Gasoline		Gas Naphtha	
	Deg. F.	Gravity	Deg. F.	Gravity
Distillation over	117		215	
10%	160	82.1	240	57.0
20	170	79.0	246	55.0
30	179	75.3	253	54.1
40	190	70.9	260	52.8
50	208	66.0	270	51.3
60	222	61.8	280	50.2
70	239	57.7	293	49.1
80	261	64.2	306	47.5
90	293	50.4	332	45.4
98 dry point	339	.....	350	

The secondary residual oil obtained in the above process had the following tests, when freed of aluminum chlorid:

Color	Red, green bloom
Flash	185° F.
Fire	250
Viscosity	105

This residual oil was reduced with steam in order to make lubricating oil.

Yield.	Per Cent Charge.	Per Cent Crude.
Gas oil	10.00	2.84
Lubricating oil	90.00	25.58
Total	100.00	28.42

Tests on Lubricating Oil

Color	Red, green bloom
Gravity	21.9
Flash	290
Viscosity	122

Summary of Yield of Products from Texas Crude by the Aluminum Chlorid Process

	Per Cent Crude.
Primary gasoline	0.30
Secondary gasoline	17.45
Primary gas naphtha	0.18
Secondary gas naphtha	12.85
Primary kerosenes	2.79
Secondary kerosenes	5.87
Gas oil	17.15
Lubricating oil	25.58
Total	82.17

Loss account distilling primary distillate	1.60
Loss account distilling with aluminum chlorid	14.60
Loss account redistillation of primary distillate	0.08
Loss account redistillation of secondary distillate	1.55
Total	100.00

The following table compares the yield of products from Texas crude by the aluminum chlorid process with the yield of products as obtained when the crude is distilled in the usual manner:

	Per Cent Crude Aluminum Chlorid Process.	Per Cent Crude Usual Process.
Gasoline	17.75	zero
Gas naphtha	13.03	0.10
Kerosenes	8.66	4.30
Gas oil	17.15	52.00
Lubricating oils	25.58	25.50
Asphaltic residual oil	.....	12.00
Total	82.17	93.90
Loss	17.83	6.10
Total	100.00	100.00

In ordinary practice no gasoline is obtained from this type of Texas crude; by the aluminum chlorid process 17.75 per cent is obtained and those who are familiar with the tests on petroleum products will see that this gasoline is as good as the natural gasoline made from any crude petroleum. The gas naphtha, which might very well be mixed with the gasoline, has been increased from 0.1 per cent to 13.03 per cent. It will be observed that these low boiling oils have been made at the expense of the gas oil fraction and the asphaltic residual oil, the latter being broken down completely. Gas oil is the least valuable constituent of the crude. The asphaltic residual oil is used for fuel or is made into asphalt. The yield of lubicating oil by the aluminum chlorid process is about the same as that in the usual process, but the quality of the former is greatly improved by virtue of the saturating effect of the aluminum chlorid and the elimination of asphaltic and resinous constituents from the oil. I have samples here of these products that I shall be glad for any of you to examine.

It will not be necessary to go into so much detail with the remaining crudes of which I desire to speak, but I have wanted to give you these figures on Texas crude to show how regularly the reaction proceeds over a long period of time, what the physical

characteristics of the products are, and the yield as compared with the usual process.

A Caddo (Louisiana) crude of 41 gravity was distilled to free it from moisture and natural gasoline.

Yield.	Per Cent Crude.
Primary distillate	26.19
Primary residual oil	71.43
Loss	2.38
Total	100.00

TESTS ON PRIMARY DISTILLATE

Gravity	58.2
Distillation over	160° F.
10%	215
20%	232
30%	247
40%	260
50%	276
60%	296
70%	315
80%	343
90%	402
95%	450
Dry point	500

The primary distillate on fractional distillation yielded:

Yield.	Per Cent Charge.	Per Cent Crude.
Gasoline	82.00	21.48
Kerosene	15.00	3.93
Loss	3.00	0.78
Total	100.00	26.19

Five per cent by weight of aluminum chlorid was added to the primary residual oil and the mixture brought to boiling. Distillation was continued for forty-eight hours, the temperature of the vapor line at the point of exit into the final condenser being held around 350° F.

Yield.	Per Cent Charge.	Per Cent Crude.
Secondary distillate	58.33	41.67
Secondary residual oil	26.20	18.71
Loss (gas and coke)	15.47	11.05
Total	100.00	71.43

TESTS ON SECONDARY DISTILLATE

Gravity	54.0
Distillation over	102° F.
10%	212
20%	260
30%	293
40%	315
50%	340
60%	365
70%	388
80%	414
90%	450
95%	480
98 dry point	500

The secondary distillate on fractional distillation yielded the following products:

Yield.	Per Cent Charge.	Per Cent Crude.
Gasoline	50.00	20.84
Solvent oil	40.00	16.67
Gas oil	6.00	2.50
Loss	4.00	1.66
Total	100.00	41.67

Following are the tests on the gasoline and solvent oil:

	Gasoline.	Solvent Oil.
Color	W.W.	W.W.
Odor	Sweet	Sweet
Bromine No.	2	3
Dr. test	O.K.	O.K.
Heat test	2	2
Gravity	58.0	48.1
Distillation over	120° F.	340° F.
10%	198	354
20%	221	360
30%	240	364
40%	258	369
50%	272	374
60%	288	381
70%	301	390
80%	322	400
90%	348	416
95 dry point	362	430
98 dry point		440

Tests on Secondary Residual Oil

Color	Red, green bloom
Gravity	36.5
Flash	260° F.
Fire	300
Pour	90° F.

This residual oil was distilled until 30 per cent of the charge had been distilled over.

Yield.	Per Cent Charge.	Per Cent Crude.
Gas oil	30.00	5.61
Paraffin residual oil	70.00	13.10
Total	100.00	18.71

Tests on Paraffin Residual Oil

Color	Amber
Pour	105° F.
Flash	375
Fire	420

Summary of Yield of Products from Caddo (Louisiana) Crude Oil by the Aluminum Chlorid Process

	Per Cent Crude.
Primary gasoline	21.48
Secondary gasoline	20.84
Secondary solvent oil	16.67
Primary kerosene	3.93
Gas oil	8.11
Paraffin residual oil	13.10
Total	84.13
Loss account aluminum chlorid distillation	12.71
Loss account working distillates into standard products	3.16
Total	100.00

The following table compares the yield of products from Caddo crude by the aluminum chlorid process and the yield of products as obtained in usual practice:

	Per Cent Crude Al_2Cl_6 Process.	Per Cent Crude, Usual Process.
Gasoline	42.32	18.00
Solvent oil	16.67	12.00
Kerosenes	3.93	35.00
Gas oil	8.11	21.00
Paraffin residual oil	13.10	11.00
Total	84.13	97.00
Loss	15.87	3.00
Total	100.00	100.00

This crude belongs to the same type as Pennsylvania crude,—the type known as paraffin base crude. Their products are clean smelling and require but little acid in refining. But even this type of crude is considerably improved by the aluminum chlorid process, while at the same time the yield of gasoline is greatly increased. The paraffin residual oil from Caddo crude is black and tarry on account of the presence of asphaltic constituents, but these are not usually present in large enough amounts to prevent the manufacture of good paraffin and paraffin lubricating oil. The distillation with aluminum chlorid destroys the asphaltic constituents, giving an amber colored residual oil which may be easily worked into a product, commercially known as vaseline, or into paraffin and paraffin lubricating oils. At the same time the yield of gasoline from the crude is increased from 18 per cent to 42.32 per cent.

An Oklahoma crude of 34 gravity was distilled to free it from moisture and natural gasoline.

Yield.	Per Cent Crude.
Primary distillate	20.83
Primary residual oil	78.31
Loss	0.86
Total	100.00

TESTS ON PRIMARY DISTILLATE

Gravity	54.1
Color	W.W.
Distillation over	152° F.
10%	210
20%	226
30%	242
40%	252
50%	271
60%	290
70%	313
80%	345
90%	408
95% dry point	455

This primary distillate on fractional distillation yielded the following:

Yield.	Per Cent Charge	Per Cent Crude.
Gasoline	70.00	14.58
Kerosene	20.00	4.17
Gas oil	7.50	1.56
Loss	2.50	0.52
Total	100.00	20.83

TESTS ON PRIMARY RESIDUAL OIL

Color	Black	Distillation over	330° F.
Gravity	29.8	10%	436
Flash	170	20%	484
Fire	205	30%	543
Pour	20	40%	590
		Below 600° F	43%

To the primary residual oil was added 5 per cent by weight of aluminum chlorid. Distillation was then continued for a period of forty-eight hours, the temperature of the vapor line at the point of exit into the final condenser being held around 350° F.

	Per Cent Charge.	Per Cent Crude.
Secondary distillate	64.61	50.60
Secondary residual oil	17.97	14.07
Loss	17.42	13.64
Total	100.00	78.31

TESTS ON SECONDARY DISTILLATE

Gravity	48.3
Distillation over	140° F.
10%	225
20%	270
30%	294
40%	326
50%	358
60%	382
70%	413
80%	454
90%	503
95%	547
98% dry point	570

On fractional distillation this secondary distillate yielded the following:

	Per Cent Charge.	Per Cent Crude.
Gasoline	40.00	20.24
Kerosene	50.00	25.30
Gas oil	7.50	3.80
Loss	2.50	1.26
Total	100.00	50.60

Tests on Gasoline

Color	W.W.	Distillation over..	130° F.	Gravity
Odor	Sweet	10%.....	160	83.8
Bromine No	1.5	20%.....	186	76.2
Dr. test	O.K.	30%.....	200	70.1
Heat test	2	40%.....	213	66.6
Sulphur	.027	50%.....	222	62.8
Gravity	64.5	60%.....	238	60.4
		70%.....	252	58.5
		80%.....	270	56.1
		90%.....	299	53.3
		Residue.....	8.3%	48.2

Tests on Secondary Residual Oil

Color	Red, green bloom
Gravity	28.2
Pour	90° F.
Flash	230° F.

This secondary residual oil was distilled to produce wax stock and cylinder oil.

Yield.	Per Cent Charge.	Per Cent Crude.
Wax stock	60.00	8.44
Cylinder oil	40.00	5.63
Total	100.00	14.07

Summary of Yield of Products from Oklahoma Crude by the Aluminum Chlorid Process

	Per Cent Crude.
Primary gasoline	14.58
Secondary gasoline	20.24
Primary kerosene	4.17
Secondary kerosene	25.30
Gas oil	5.36
Residual oil	14.07
Total	83.72
Loss account aluminum chlorid distillation	13.64
Loss account working distillate into standard products	2.64
Total	100.00

The following table compares the yield of products from Oklahoma crude by the aluminum chlorid process and the yield of products as obtained in usual practice:

	Per Cent Crude. Aluminum Chlorid Process.	Per Cent Crude. Usual Process.
Gasoline	34.82	12.50
Kerosenes	29.47	41.00
Gas oil	5.36	35.00
Residual oil	14.07	9.00
	83.72	97.50
Loss	16.28	2.50
Total	100.00	100.00

The residual oil from this crude by the usual process is a black, tarry mass, containing large amount of asphaltic constituents and also paraffin. The amount of asphaltic constituents is so great, as a rule, that it is difficult to make paraffin and paraffin lubricating oils of the same grade as that obtained from Pennsylvania or Caddo residuums. By the aluminum chlorid process this residual oil is cleaned of its asphaltic constituents, and paraffin wax and paraffin lubricating oils of excellent quality are made therefrom. At the same time, the yield of gasoline from the crude is greatly increased, at the expense of the less valuable fractions of the crude.

Although the crude petroleums from the various oil producing districts in this country differ greatly in quality and in chemical composition, yet they are generally divided into three types: Asphaltic-base crude, paraffin-base crude, and paraffin-asphaltic-base crude. The oils I have spoken of in this paper are representative of each of these types; Texas, asphaltic-base crude, Caddo, paraffin-base crude, and Oklahoma, paraffin-asphaltic-base crudes. To give figures on other crudes would be merely a repetition of the results obtained on one of these. I shall therefore not take the time to give further examples. I might add that among the samples here are products made by the aluminum chlorid process from 14 gravity California crudes and 20 gravity Mexican crudes.

But all the good results of this process would be of no commercial value if the aluminum chlorid could not be reclaimed. This chemical when made on the ton scale is not so expensive as it is when made on the pound scale, but nevertheless its cost is high, and from a dollars and cents point of view, it is necessary to recover it. And this is done by the processes set forth in my patents.

After a time, forty-eight hours or longer, aluminum chlorid used

in distilling oils, even the driest of oils, loses its catalytic activity and becomes converted into a coky mass. Analysis of the coky mass shows chlorin and aluminum present in the right proportions to form aluminum chlorid, but the latter is, so to speak, masked. It does not display its ordinary reaction with petroleum hydrocarbons. The granular coky residue after it comes from the oil converting process, carries varying amounts of oils with it. If allowed to cool down in the presence of the body of oil, it may carry 40 to 50 per cent of its weight of oil. If the oil body has been separated while hot from the coky residue, the amount of oil will be reduced to 4 or 5 per cent.

After removing the oil, or the bulk of it, from the coky residue, the aluminum chlorid can be extracted from the latter with water or steam to obtain a concentrated solution of hydrated aluminum chlorid. Aluminum chlorid in the hydrated state does not have the catalytic property of the anhydrous material; but the hydrated salt can be used as the raw material for making the anhydrous salt. To do this, advantage is taken of the property of hydrated aluminum chlorid breaking up when moderately heated to form aluminum oxid and hydrochloric acid gas. The alumina when mixed with carbon and treated with hydrochloric acid vapors at a high temperature, react to form the anhydrous chlorid, hydrogen and oxids of carbon. In utilizing this property, one portion of the hydrated chlorid is heated to produce hydrochloric acid vapors and alumina, and these vapors on drying enter a further charge of alumina and carbon heated to redness. The hydrochloric acid vapors given off at a moderate temperature are thus utilized in further operations at high temperatures.

In another method of recovery, and the preferred one, the coky residue is heated to red heat in an atmosphere of chlorin which disengages the aluminum chlorid from the carbon. Aluminum chlorid volatilizes normally at a temperature around 365° F. but the coky residue may be heated to redness without much evolution of these vapors. If the heating is done in an atmosphere of chlorin, the aluminum chlorid is unlocked, so to speak, and vaporizes away from the carbon, and is condensed in suitable receivers.

Of course, the last and ultimate test of any process is whether it will work, and work successfully without undue petting. That the aluminum chlorid process is now an assured commercial success, is, of course, due to its own merits. But I cannot forego this

opportunity to speak of the generous aid from the Gulf Refining Co. which has made success possible, and the valuable advice and help from its officers.

Although this account by no means covers the full scope of the aluminum chlorid reaction with petroleum oils, yet to speak further would lead me outside of my subject. It is with deep satisfaction that I have been privileged to read this paper before the American Institute of Chemical Engineers, in the capacity of a recent initiate among you; and I trust I may have the pleasure of reading further papers before you in due course of time.

DISCUSSION

The CHAIRMAN: The Institute is obliged to Mr. McAfee for his very interesting and instructive paper on this subject. It is a custom of the Institute to allow questions and discussion of papers. I wish to remind the members, however, that our time is progressing owing to the business session and that the discussion should be limited as far as possible to the most necessary questions.

Prof. SADTLER: This paper I suppose will appear in the proceedings?

Sec. OLSEN: Certainly.

Prof. SADTLER: I believe I am right in having understood Mr. McAfee that this paper will be published in the *Journal of Industrial and Engineering Chemistry*.

Mr. MCAFEE: Yes.

Mr. KLOTZ: I should like to ask one question in regard to the Louisiana crude. Mr. McAfee said that in the operation of this paraffin-base crude there were some asphaltic bodies destroyed. If there are asphaltic bodies present can that Louisiana crude be looked upon as strictly paraffin crude and would there be any difference between that and Pennsylvania crude which is a strictly paraffin base?

Mr. MCAFEE: I am not acquainted particularly with the Pennsylvania crude though I am told that most of the Pennsylvania crudes contain small amounts of asphalt, so that when you reduce them down to the point where paraffin comes over they will be black, the same as Caddo.

Mr. KLOTZ: What is the percentage of the asphaltic constituents?

Mr. MCAFEE: I do not know the exact percentage in Pennsyl-

vania crude, neither do I know in the Caddo; but it is not there in sufficient amounts to interfere with the manufacture of paraffin and paraffin oils from Caddo crude.

Mr. ALEXANDER: Mr. McAfee, what district in California did that California crude oil come from? I ask that because some California crude oil contains a substance which is very much like paraffin. I believe there is a certain amount of scale, 1 or 1½ per cent, in the Texas oil.

Mr. MCAFEE: As regards the California crude I am unable to state where that came from. I had a small sample of the California crude shipped me through a friend, and he did not advise me as to its source. The Texas crude, figures on which are given here, contained no paraffin.

Mr. LACHMAN: I would like to ask Mr. McAfee a question in regard to the commercial side of this aluminum chlorid. Aluminum chlorid is expensive and your recovery is expensive but you get more valuable products. What is the net percentage of gain in value due to this process after deducting the cost of operation?

Mr. MCAFEE: I am unable to answer that.

Prof. SADTLER: I would like to ask Mr. McAfee if the percentage of asphalt has been determined by the Holde process.

Mr. MCAFEE: That is the usual method.

Prof. SADTLER: What is the percentage in the Caddo crude?

Mr. MCAFEE: I don't recall just what it is, but I would say between 2 and 3 per cent.

Mr. MATTHEWS: You said something about the heavy oils refluxing into the still. Is there a tendency for them to crack as they go back into the still?

Mr. MCAFEE: Cracking is not generally obtained below a temperature of 650° F., and in the aluminum chlorid process we never reach that temperature; so whatever breaking down is done is done by the aluminum chlorid and not by heat.

Mr. ISAACS: Suppose your secondary distillate has been refractionated and all the gasoline stock taken out of it you have a remainder that contains your engine distillate and kerosene stock. You could return that to the still to be acted upon, could you not?

Mr. MCAFEE: Yes; the returned stock would be acted upon the same as the starting material.

Mr. ISAACS: That would effect a still higher yield of gasoline?

Mr. MCAFEE: Yes.

The CHAIRMAN: Did I understand you to say that the products are at once returned to the still from the first air condenser?

Mr. MCAFEE: Most of the aluminum chlorid and compounds are returned at the dome. The high boiling hydrocarbons are returned to the still from the air cooled condensers located between the dome and final or water cooled condenser.

The CHAIRMAN: And that is returned to the still?

Mr. MCAFEE: Yes, the condensed hydrocarbons are returned to the still.

Mr. BARUCH: If the question is not too impertinent will you be so kind as to state the percentage of aluminum chlorid recovered?

Mr. MCAFEE: I am not able to give that now.

Prof. O'NEILL: Do you find that sulphur has any effect on your process?

Mr. MCAFEE: Yes; sulphur seems to effect the aluminum chlorid activity.

Prof. O'NEILL: Diminishes it?

Mr. MCAFEE: Diminishes it, yes.

Prof. O'NEILL: But it does not inhibit it entirely, does it?

Mr. MCAFEE: No.

Prof. O'NEILL: That is corrected by increasing your aluminum chlorid?

Mr. MCAFEE: Yes; the more you increase the aluminum chlorid within certain limits, the higher the percentage of low boiling products obtained.

Prof. O'NEILL: You don't use pressure?

Mr. MCAFEE: No.

Prof. O'NEILL: But if you increase the temperature then you increase the rapidity of your reaction?

Mr. MCAFEE: I can't say. It is rapid enough I should say at the temperature obtaining under ordinary pressure.

Prof. O'NEILL: On how large a scale have you carried out this work?

Mr. MCAFEE: I am just now getting the plant to a thousand barrel capacity.

Prof. O'NEILL: Heretofore it has been carried on on a relatively small scale.

Mr. MCAFEE: Yes.

Mr. ALEXANDER: I would like to ask Mr. McAfee one more

question. You stated that the cracking point comes at a point over 600.

Mr. McAfee: Around 650° F.

Mr. Alexander: Well, in California our oils will begin to crack at about 450, am I not right?

Prof. O'Neill: Beginning about that.

Mr. Alexander: Anyhow cracking of California crudes takes place at lower temperature than with Eastern and Mid-Continent crudes. Would that have any effect on the odor of the gasoline or would it be obviated by the use of aluminum chlorid?

Mr. McAfee: I don't believe it would because it takes very little aluminum chlorid to saturate and sweeten the most cracked products.

Mr. Alexander: It would be available then with any of our California crudes?

Mr. McAfee: Yes.

The Chairman: Any further questions?

Prof. Sadtler: Will the specimens be put out so we can see them before we leave the room?

Mr. McAfee: Yes.

The Chairman: They will be accessible at the close of the session.

SOME AMERICAN CONTRIBUTIONS TO INDUSTRIAL CHEMISTRY

By SAMUEL P. SADTLER, Ph.D.

Read at New York Meeting, September 24, 1915.

You will notice that I have limited the subject matter of my brief address to what I call American Contributions to the Field of Industrial Chemistry. And even this field I will restrict by leaving to one side the discussion of what we have contributed to well-established industries of European origin, or how we have worked on lines already clearly mapped out for us by the prior establishment and successful operation of those industries abroad.

I do not wish to say that such contributions of American Chemists to some of the older and long-established industries have been of so slight a value as to be unworthy of mention. On the contrary, the part that American chemists and engineers have taken in the development of some of the older industries, such as the manufacture of acids, alkalies, and of heavy chemicals, of pigments of soaps and glycerin, paper-making, leather manufacture, and certain metallurgical lines, has been quite important. Most of this has received deserved recognition in the series of reports prepared within the last year for the Industrial Division of the American Chemical Society and published in its *Journal of Industrial and Engineering Chemistry*.

However, there are some very important chemical industries that took their start with us in this country and have been developed, too, in most cases, to flourishing condition without borrowing any notable help from abroad. These we should point out to those of the public who have not learned that we have anything distinctively our own as yet, and who think that because we cannot command our antebellum supplies of potash and organic dye-colors at present we must start in and establish the manufacture of chemicals as a new venture for this country.

With the wonderful richness of this country in the raw materials

which lie at the basis of chemical industries, and with the well-known inventive and mechanical turn of our people, we would be greatly disappointed if we did not find some results in the way of the establishment of new and distinctive lines of manufacture and the production of new products for which uses were speedily found. We desire to make, this evening, brief reference to some of these American-developed chemical industries.

The first to note chronologically as well as the first in importance is the great petroleum industry. Isolated occurrences of natural oils, combustible in character, had been observed in various parts of the world, just as natural gas had been noted as a matter of interest to the mineralogist and to the traveler. For instance, in 1833, the elder Silliman and, in 1836, Dr. S. P. Hildreth described the occurrence of oil springs. From the surface of these the Indians had collected what was called Seneca oil. I have myself a pint sample of such oil from a spring in Ohio that is reported locally to have yielded oil from 1813 to the present. The Rock Oil Company, which afterwards became the Seneca Oil Company, had engaged Col. E. L. Drake as its manager, and on August 28, 1859, he struck oil at a depth of 69 feet in a well that he had drilled near Titusville, Pa., which started off with a daily yield of 25 barrels. From this mustard-seed has grown the great American petroleum industry, which in 1914 produced 265,762,535 barrels, or 66.36 per cent of the world's production.

However, it is not simply a question of being first in the discovery of how to obtain the oil from its subterranean deposits. The distillation of the crude oil for the purpose of separating the lighter from the heavier portions and refining them so that they could be used as burning oils, lubricating oils, etc., was developed entirely independently in this country. The distilling of shale oil and the preparation of a merchantable product for use as an illuminant under the name of "coal-oil" had already been practised when Drake's discovery was announced and petroleum distilleries speedily sprang up. Then the accidental discovery, as it is claimed, of the possibilities of increasing the yield of light fractions by what is known as "cracking," about 1865, made it possible to get a maximum yield of kerosene fraction from the crude.

When, later, the large production of a crude oil in California, differing greatly from the Pennsylvania crude first developed industrially, led to the establishment of the distinction between

paraffin-base crudes and asphalt-base crudes, the preparation of an artificial asphalt from California oil followed.

Because of the large utilization of asphaltic materials for paving, roofing, waterproofing, etc., the manufacture of artificial asphalts by the blowing of hot oil residuums generally, according to either the Byerley or the Culmer patents, followed, and it is now possible to get, in this way, solid products of every grade of ductility and penetration and a wide range of melting-point which find a great variety of uses.

It must not be overlooked that the industry owes much also to the engineering ability of the men connected with its early development. The enormous extent of the producing field would have made the question of the transportation very serious had not the tank car and the pipe-line soon developed to relieve them. These were the fruit of American invention, while the Russian oil industry is to be credited with the introduction of the oil-tank steamer now in general use.

I have referred to the early use of "cracking," as practiced in the handling of the crude oil stills of most refineries in order to increase the burning oil fraction at the expense of the heavy oils. This has been followed by efforts to increase notably the gasoline or light naphtha percentage, which in recent years has become more important and commands a higher price than the burning oil. In place of the cracking by causing condensed heavy vapors to drop back upon a superheated oil layer in the still, but working under normal pressure, which involves much waste by formation of uncondensable gas and separation of carbon, recourse was had to distillation under pressure, as in the Burton process, now largely used by the Standard Oil Company in several of its largest refineries and with a considerable measure of success. Still more recently the principle of distillation under heavy pressure and at higher temperatures has been brilliantly applied by Dr. Rittman, with the result of the production of large amounts of gasoline or, at higher pressures, of benzene and toluene (aromatic hydrocarbons) in notable amount. This process is now being given a large-scale experimental trial by the Ætna Chemical Company, of Pittsburgh.

A somewhat similar process of decomposition of petroleum by heating under very high pressure has been described in outline by

Walter O. Snelling, but the full account of the method and results has not as yet been published.

Radically different from these processes of cracking under pressure is the recently described process of McAfee, who utilizes the Friedel and Crafts reaction with anhydrous aluminum chloride and, after getting off the normally present gasoline and kerosene, runs the distillation of the heavy oils at about 500° to 550° F. with the aluminum chloride, obtaining, as a result, saturated hydrocarbons in both the gasoline and kerosene fractions produced. Mr. McAfee's paper has just recently appeared in both *Metallurgical and Chemical Engineering* and *Journal of Industrial and Engineering Chemistry,* and is worth careful study. I heard him give an account of his results at the San Francisco meeting of the American Institute of Chemical Engineers, and examined his samples of oils as used and obtained in his work.

My account of the American development of the petroleum industry would be incomplete did I not mention the rapid development of the production of gasoline by the condensation of natural gas accompanying crude petroleum, or what is called "casing-head gas." Bulletin No. 88 of the Bureau of Mines, Department of the Interior, on "The Condensation of Gasoline from Natural Gas," by Burrell, Seibert, and Oberfell, issued this year, gives a very complete picture of this new industry. I merely give the summaries of amounts of gasoline so produced in recent years: 1912, 12,081,179 gallons; 1913, 24,060,817 gallons. Of course, this gasoline with a gravity of 85° to 90° B. is reduced by blending it with naphtha distillate.

A second great industry developed in this country is the working up of native rock phosphate of lime into a fertilizer product. Of course, the value of phosphoric acid as an element in the fertilization of the soil was already indicated by Liebig, the great chemical founder of scientific agriculture, and the use of the rich native phosphates known as guano was extensively followed. But the opening up of the South Carolina phosphate rock beds in 1870, followed by the discovery of the still more abundant deposits of Florida in 1888 and of Tennessee in 1893, furnished the material for what was practically a new and American industry. The mining of rock phosphate and the manufacture of superphosphate fertilizers henceforth went hand in hand, with the result that one of the great chemical industries of America was developed. Reckoned

by tonnage of products, it is the largest of our chemical industries, and it is important, too, as consuming fully one-half of the American sulphuric acid production, far exceeding all other industries in this respect.

I shall not take the time here to trace the development of this industry, but would like to add a few words to show the magnitude of our resources in raw materials in this line.

Dr. H. K. Benson, in his paper, read at the recent Seattle meeting of the American Chemical Society, on the "Resources of the Northwest," said that the phosphate deposits of Idaho were thirty times greater than the other deposits in the United States. The United States Geological Survey estimates that these Idaho deposits contain 2500 million tons of phosphate rock with 35 to 37 per cent P_2O_5.

Related to this phosphate fertilizer industry is our utilization of animal scrap and waste for analogous use as fertilizer material. I will note three principal sources of supply of this material: First is the tankage and scrap of the great packing-houses at Chicago, Kansas City, Omaha, etc.; second, the menhaden fish residue of our Atlantic coast, after the oil has been extracted; and, third, the waste of the salmon and other fish-canning industries on the Pacific coast. With regard to this latter, Dr. H. K. Benson, in his paper on the "Resources of the Northwest," stated that from a packing of eight million cases of salmon in 1913, 140,210 tons of cannery waste was obtained. Of the amount of material from the other sources named I have no present information.

Another great industry, while not created *de novo,* has been profoundly modified by an American invention which was developed and in use here for years before it was taken up abroad. I refer to the water-gas manufacture. This was the invention of Thaddeus S. C. Lowe, who had already established a creditable reputation as a military aeronaut in our Civil War. The Lowe water-gas process of 1872-75 afterwards was acquired by the United Gas Improvement Company of Philadelphia and underlies the present large manufacture of this type of gas, whether carburetted or otherwise, which is practised in this country and in Europe upon the continent. The Germans followed in 1886, and with an improved form of apparatus in 1895.

More recently we have seen another old-established chemical industry revolutionized by an American invention, which had the

effect of establishing what might be called a new and highly successful American industry. I refer to the American production of sulphur in Louisiana by the aid of the Frasch process of extraction of the sulphur in melted form by pumping it from the depths where it is found. This American production of a nearly pure native sulphur has completely stopped the importation of Sicilian sulphur, and was, at the outbreak of the present war, competing with the Sicilian product in Mediterranean ports.

We have two distinctively American products in the vegetable kingdom which serve to furnish the starting-point or raw materials for two highly developed American chemical industries, viz., the cotton plant, furnishing the cotton seed and its products, and the maize or Indian corn, furnishing corn starch and its alteration products, together with corn oil and gluten.

The cotton seed and its products have become among the most valued assets of the cotton planter. From each ton of cotton seed over 300 pounds (40 to 50 gallons) of oil can be obtained, which, when properly refined, furnishes us one of our most valuable oils, both for technical use, as soap stock, and for food purposes. Hundreds of mills throughout the South are engaged in pressing this cotton oil, as it is called; enormous quantities have gone to be blended with stearine to make so-called compound or substitute lard, and other large amounts brought to a white, deodorized condition, used directly for food and baking purposes. More recently it has been converted into a soft, white, solid condition by the hydrogenating treatment, and in that form is again available as an edible oil for cooking and baking. After the expulsion of the oil, we have left the oil-cake, which, ground to meal, makes a very valuable feeding stuff or addition to fertilizers because of its nitrogen content. The hulls, burned as fuel, yield an ash rich in potash and phosphoric acid, hence of immediate value in the making up of fertilizers. The success with which the cotton seed, at one time a waste product, after the removal of the seed hair or valuable fiber by ginning, has been turned into a source of wealth for a great section of our country, illustrates how a great chemical industry was built up and values created out of material at first entirely neglected. The other distinctively American industry that I coupled with the cotton-seed industry was the utilization of maize or Indian corn, and has come to be known generally as the corn-products industry.

While the starch production from wheat, potatoes, and rice had

been worked out elsewhere, and while a hydrolyzed product of syrupy consistency had also been obtained from potato starch, the manufacture of corn starch and of corn syrup, the latter first known as glucose, was worked out in this country, and upon and around this has been built up a great industry, producing a great range of products of great commercial importance. Corn starch was manufactured in this country as early as 1848, at Oswego, N. Y., but until about 1881 little but the starch itself was recovered or sought to be recovered. To-day, besides recovering the starch in a high state of purity, the germ is made to yield the valuable corn oil and an oil-cake for cattle feeding; the gluten is recovered in a dry state and, mixed with the ground hulls, makes a nitrogenous cattle food. The extractive matter (or corn-solubles) from the steep water is now also saved and incorporated with the gluten feed. The starch may be marketed as dry starch of various grades and prepared for a variety of uses, as dextrines of various colors and qualities, or as more or less hydrolyzed products, known as corn sugar and corn syrup. The oil is used in the manufacture of soap, soap powders, in the tanning industry and in paint, and, what is of interest, affords, when vulcanized, an excellent rubber auxiliary or rubber imitation. It is also a source of glycerin, while the free fatty acids find ready use by the soapmaker. In fact, this industry, in its present-day development, is one of the best illustrations of a scientific American chemical industry, working up a distinctive American raw material in the most complete way.

Without looking around for further individual illustrations of American-developed chemical industries, we now turn to a group of industries of American founding and developing which have taken a great lead in the world's industrial progress. I refer to the part which America has played in the electro-chemical and electro-metallurgical industries, several of the most important of which are based upon the discoveries of American chemists and have been brought to a high state of development by their continued effort.

The first of these American inventions was the Hall aluminum process, dating back to 1886, the date of his patent application. This fundamental discovery of the method of electrolyzing alumina dissolved in a bath of fused cryolite has now supplanted all other methods, and the manufacture of metallic aluminum everywhere throughout the world is practically based upon it. What is of more importance for our present argument is that a great American in-

dustry has developed from it and we have become the leaders in the manufacture of this important metal because of it. The history of this discovery has been repeatedly told and the importance of aluminum in the arts has been pointed out, so I will not dwell upon that side of the subject.

We have next two important industries, both based upon the discoveries of an American chemist. I refer to the carborundum industry and the manufacture of artificial graphite, both based upon the discoveries of Dr. E. G. Acheson and now flourishing lines of manufacture at Niagara Falls, N. Y. The carborundum or silicon carbide is formed in the electric furnace and finds an extensive use as an abrasive under a great variety of forms, having a hardness almost equal to that of the diamond. The artificial graphite is a product of a reaction similar to that indicated for carborundum, but carried through at a higher temperature, whereby the silicon is evaporated, leaving the residual pure carbon as soft metallic graphite. This latter is so free from impurity that it may serve as the basis of the finest lubricating mixtures. These specially prepared lubricants, known as aquedag and oildag, according as they are brought in suspension in water or oil admixture, have proved of special value.

One of the great industries based upon electric furnace work is the manufacture of calcium carbide, which in itself, as a source of acetylene and as the necessary material for use in other great industries, as the cyanamide manufacture, is now produced throughout the world in large and increasing amount. While calcium carbide as a chemical compound had been discovered by Wöhler in 1862, and while Moissan had obtained it in his electric furnace independently about the same date as Willson, the production of it by electric furnace reaction on a working scale was due to Willson at Spray, N. C., in 1892, who may therefore be said to have founded the calcium carbide industry. This industry has spread to all countries where cheap water power is available for the generation of electricity, and in this country is strongly established at Niagara Falls and at Sault Ste. Marie, besides the use above referred to in the manufacture of calcium cyanamide, which has also been started in this country.

The manufacture of electrolytic caustic soda and chlorine has also had a very creditable showing in this country in recent years, and in this connection several American types of cells have been

successful. I refer to the Castner electrolytic cell, which has operated successfully for a term of years, and the Townsend cell, of more recent development. By the aid of these inventions it has been made possible to establish at Niagara Falls several flourishing chemical industries and to give an impetus to the movement for the emancipation of the United States from dependence on European chemical manufacture.

I have thus sketched the development and establishment of a number of chemical industries of distinctively American origin. My list is not intended to be an exhaustive one. It could readily have been extended. It is enough, however, to show that we have done very creditably and, in fact, have done much more than is generally known to the public.

As I said in beginning these remarks, "With the wonderful richness of this country in the raw materials which lie at the basis of chemical industries, and with the well-known inventive and mechanical turn of our people, we would be greatly disappointed if we did not find some results in the way of the establishment of new and distinctive lines of manufacture and the production of new products."

So much for the establishment of new industries. However, unless the supply of raw materials is so specially limited to the country as to preclude their becoming available elsewhere, a time will come for an important industry when the manufacture becomes competitive in an international sense. Then a national policy with regard to established industries becomes of the greatest importance. Legislation can foster these industries in a great variety of ways, or it can hamper them so that international competition soon puts them at a disadvantage.

If we are to maintain our chemical manufactures already begun and reach out for a stronger and more independent position in industrial chemistry, the matters of legislation, the tariff, and our patent laws must be given intelligent thought and such action taken as will give us a fair show in the world's competition. As that is a large subject, involving many considerations, I will not enter upon it here.

THE DEVELOPMENT IN THE UNITED STATES OF THE MANUFACTURE OF PRODUCTS DERIVED FROM COAL

By H. W. JORDAN

Read at the Baltimore Meeting, January 12, 1916.

During 1915 we read statements in the press almost daily, which gave the impression that our American chemical industry was wholly unable to manufacture synthetic coal products, and that the only relief in sight was from the wonderful discoveries of a small group of chemical amateurs, who, having patriotically hurled themselves into the situation since the war began, were on the verge of evolving the entire 900 synthetic coal-tar dyes and the whole list of pharmaceuticals from palmetto and other sources, hitherto unsuspected as being fundamental to organic chemical products. These statements, by implication, and by omitting mention of the extensive plants erected and put into operation by the old, established chemical companies in 1915, tended to create the public belief that these companies were doing nothing to supply the American market.

Some of the most important products which were widely heralded as having been produced for the first time in America in 1915 were manufactured by these companies 15 to 30 years ago. Benzol and its homologues have been regular American products, with shipment in carload lots or tank cars, and with occasional exportation to Europe, since 1900. Salicylic acid was manufactured at Jersey City by Zinsser & Company from 1880 until 1897, when foreign competition closed the plant.

Synthetic Carbolic Acid was manufactured by the Semet-Solvay Company from benzol at Syracuse in 1900 and the following years, in quantities up to 2500 pounds daily. This carbolic acid was synthesized into trinitrophenol, commonly known as picric acid, which was bought by the United States Government for use in national defense. The United States had several well-equipped plants, prior to 1885, for manufacturing the principal coal-tar dyes

of that day. The industry grew, and produced an increasing number of synthetics, from which all those survive which could surmount the natural and artificial barriers in the road to a complete American coal-tar products industry. The principal ones of these manufacturers have continued without interruption, and constitute the main body of our present organic chemical industry.

The failure to give credit in the daily press for the large amount of capital invested, and for the extensive work accomplished during the past year, is not fair to these American companies which built up our great American chemical industry during the past 30 years, and who are now the prime movers in expanding our American coal products industry to meet the new conditions.

THE BENZOL PRODUCTS COMPANY is an example of this growth. Organized in 1910 by men long associated with the acid, alkali and coal products industry, it began the manufacture of aniline and aniline salt at Frankford, Pa., in the aniline plant operated several years before by the late Dr. Jayne. Although the Company's output of aniline in 1910 was but a small percentage of the American consumption, the English and German producers immediately dropped the price from 10 cents or 11 cents per pound, where they had held it for several years, to 9 cents or 8 cents per pound.

Most of the American consumers of aniline refused to buy this American aniline at the fair price of 9 cents to 10 cents, at which it was offered. Instead they followed their usual custom and sacrificed the American producer by supporting the cut-rate foreign producers.

These American consumers were the very ones who rushed to Washington when the war began, and frantically implored the Department of the Interior to dig up right away, quick, through the Division of Mines, some unfailing source of supply to provide the two thousand or more synthetic coal dyes and pharmaceuticals which had required 45 years of German science and organization to develop. The trip to Washington was easy for them. They had been there repeatedly since 1880, whenever a tariff bill was under consideration, to advocate no tariff on dyes.

The Benzol Products Company received the support of a few of the most far-sighted American consumers, who realized that the permanent establishment of aniline manufacture in the United States was of far greater value than the profit for a few years on their purchase of aniline, at 2 cents per pound below its former

price. With their support the manufacture of American aniline was continued.

Since the war, a new plant was built at Marcus Hook, Pa., and put into operation in August, 1915, with ultimate capacity equal to the former United States consumption of aniline. Notwithstanding war conditions, which multiplied the price of its war materials, benzol, sulphuric acid and nitric acid, the company sold its aniline at a price less than half the prevailing market price of aniline during 1915.

This production of aniline, supplemented by that of a few other plants, has supplied the American market to a fairly comfortable extent.

The Benzol Products Company's aniline has been distributed, by preference, to those consumers who employ directly or indirectly the greatest number of people. The important fact is that in 1916 a supply of aniline equal to the former American consumption will be available at fair prices, and that this supply is not coming from mysterious nor untried sources.

BENZOL SUPPLY: Since 1900 the production of benzol has steadily increased in the United States, so that there was enough benzol at all times for the manufacture of dyes, if the industry had been established by the assistance of the Federal Government and by the sustained support of the American textile manufacturers. Not only were both these lacking but the textile manufacturers persistently favored the English and German producers in preference to any American manufacturers.

Benzol supply is only one factor, and alone it is not sufficient to justify the very heavy investments required to establish an American coal products industry.

In 1915, several steel companies operating by-product coke ovens installed benzol recovery plants, so that a heavy production of American benzol is assured. When the war ends the output from these plants will be so abundant that it may become available as motor fuel for automobiles. In this service, one gallon of motor benzol gives 15 per cent greater mileage than does one gallon of gasoline.

ACIDS AND ALKALIES THE FOUNDATION OF COAL PRODUCTS INDUSTRY: Under the abnormal conditions and inflated prices caused by the war, many small plants sprung up and have produced products derived from coal, at a profit. At the end of the war, these

plants will fall like autumn leaves. A few will struggle on and consume their war profits in the hopeless endeavor to establish permanent business. Only those built on a firm economic basis will survive.

The manufacture of products derived from coal is not an industry by itself. It is founded upon, and is an extension of, the manufacture of mineral acids and alkalies, and was created as a means of making a wider market for those acids—sulphuric, nitric, hydrochloric, acetic, for chlorine and the like, and a market for the alkali products, soda ash and caustic soda. For this reason a permanen coal products chemical industry cannot be created in America excep by co-operation with, or extension of, the American acid an alkali manufacturing companies.

THE VALUE OF EXPERIENCE: In 1915, with prices ten to fifteen times normal, it was possible to manufacture some coal products with large profit in the United States. With the return to normal conditions, we must conduct our processes with keenest attention to the most scientific methods, because losses of 1 per cent or 2 per cent in the steps of manufacture mean bankruptcy.

Proof that Americans sadly lack this scientific detail was given in 1915 by the many serious accidents, fires and explosions in plants manufacturing these products, the cause of which was faulty engineering design, inexperienced superintendence, untidy plant housekeeping and careless workmen.

With unconscious humor, we have done homage to German efficiency by ascribing these accidents to the German diplomatic service.

To illustrate the necessity of attention to detail, take the synthetic manufacture of carbolic acid. This process, starting from pure benzol, involves five chemical reactions and from ten to fifteen chemical operations, if all by-products be recovered. If an avoidable loss so small as 1 or 2 per cent be permitted in each of these steps, the final yield of carbolic acid would be so low that the process might be a commercial failure. Yet carbolic acid is one of the most simple products to manufacture.

Many others involve more steps, or steps in which the lack of technical skill produces larger loss. For example, a certain product with a normal price of 30 cents per pound has a possible maximum yield of 100 units attainable by extreme care in manufacture. With moderate care the yield drops to 88 per cent, and with ordinary

care the yield drops to 75 per cent. Expressed in dollars and cents the result per ton is:

Possible yield	100%,	2000	lbs.	@	30c.	$600.00	per ton
Usual yield	88%,	1760	"	"	"	528.00	" "
Common yield	75%,	1500	"	"	"	450.00	" "
	Loss @ 88%					72.00	" "
	Loss @ 75%					150.00	" "

NATIONALIZATION OF THE INDUSTRY. Approach to 100 per cent technical efficiency is not the only requisite for commercial success. The intricate processes yield numerous by-products. Some are acids and alkalies which must be recovered and returned for use in the process. Others are salts or coal products which must be refined and sold. For many of these no market exists in the United States.

A network of markets must be created for every one of these by-products either in the United States, in South America, Asia or Europe, if our American coal products industry is to grow with the world and pay reasonable dividends on the investment.

It is not sufficient that American consumers acquire the habit of buying chemicals "Made in the United States." Our chemical industry, to endure, must cover the world's market; indeed, its ultimate success may depend upon an American merchant marine.

The German system of nationalized industry handles this multitude of by-products with military precision, by fitting each one into the particular technical and commercial chink best suited to it, so that all by-products are marketed at or above cost. This permits the main product to be sold at a profit large enough to sustain the normal growth of the plant and to develop new products, without adding new capital, and in addition, to pay 10 to 25 per cent dividends.

In complete contrast it has been, and is, the policy of our Federal Government to forbid any such interlocking national cooperation.

NATIONAL DEFENSE. The coal products chemical industry is vital to national defense. One source of the extraordinary military strength of Germany is her ability to manufacture ammunition, literally from the air and earth, in unlimited quantity. This ability was created by the chemical industry, which built huge works and

trained an industrial army of men with the scientific knowledge and technical skill necessary to transform the nitrogen of the air, and certain ones of the coal products into ammunition. The fundamental reason for the support which the Imperial Government gave to the coal products industry was that Germany should develop a supply of ammunition adequate for national defense and world conquest.

While developing home resources, the German industry bought benzol, carbolic acid and other crude coal products from England, thus absorbing England's commercial and military strength. Meanwhile we were more backward than England, for we were so quick to grasp the red hot opportunity presented by German dyes and pharmaceuticals at low prices that we did not even take the trouble to produce enough crude coal products to export.

Ammunition cannot be manufactured in sufficient quantity during the exchange of diplomatic notes prior to war; it must be manufactured and stored long in advance of hostilities. One main national defense is that great coal products chemical plants be established and operated steadily at commercial profit during peace, so that they will be instantly available to produce unlimited ammunition during war.

In 1915 we built many ammunition plants in the United States, every one on an artificial basis; few of them can make a profit at peace prices. Unless the United States establishes a complete and profitable national coal products industry on a basis to keep abreast with all scientific progress, our programme of "National Preparedness" will descend to the plane of comic opera.

NITRIC ACID FROM THE AIR is one step in such scientific progress. Our supply of nitric acid comes now from nitrate of soda imported from Chile. After the war, if the importations are not obstructed, we will receive nitrates and nitrogenous products manufactured in Norway and Germany by fixation of atmospheric nitrogen. Part of these products will be for fertilizer, part for explosives.

Exhaustion of the nitrate of soda mines in Chile will ultimately make the United States wholly dependent upon this European supply, unless we manufacture our own nitrates and nitric acid from the air.

The potash situation is a parallel condition. With German potash cut off, we have no potash. Various American sources will

be brought into operation, but several years must elapse before we produce all the potash we consume.

Fixation of atmospheric nitrogen as nitric acid will also require several years, even though the Federal Government give the manufacture its strongest support.

Nitric acid is the effective end of every explosive and is the first chemical reagent used in the manufacture of aniline, and thence of indigo and others of the most important coal products and dyes. Without nitric acid, our entire navy, army and coast defense becomes helpless the instant the stock of ammunition is exhausted.

Our entire investment in National Preparedness will be wasted money, if it does not include the manufacture of nitric acid from the air on a scale to render us absolutely independent of foreign nitrates.

TARIFF. A reasonable tariff, if formulated upon rational lines, will be of much value in supporting our coal products manufacture. Such a tariff would divide these products into three classes according to their degree of advancement in manufacture, and would levy duties proportionate to this degree. The classes would be,—1st, Crude products. 2nd, Intermediates. 3rd, Dyes, pharmaceuticals and highly refined products. The duties should be,—On crudes 10 per cent ad valorem, Intermediates 20 per cent ad valorem and Dyes 30 per cent ad valorem.

If a specific duty be included it should be at the rate of 3¾ cents per pound on the intermediate class and 7½ cents per pound upon dyes and pharmaceuticals. There should be no specific duty on crude products.

The free list should include coal tar, coal tar pitch, creosote oil and mineral acids. Natural indigo and other natural dyes of vegetable or animal origin should be placed with synthetic dyes in class three.

Class 1—crude products—should comprise a small list. It should be described as,—all crude products of coal produced through destructive distillation of coal, or otherwise, and not refined by more than one distillation, nor refined by any process other than distillation, nor refined nor produced by synthesis; such products being crude light oils, benzol, toluol, xylol, cumol and naphthalin, crude tar acids containing less than 80 per cent pure tar acids, and all other products from coal not otherwise specially provided for, and not medicinal and not colors or dyes, the duty to be 10 per cent ad valorem.

The second, or intermediate class, should include all products manufactured from those of the crude products class, and all so-called intermediates, not colors nor dyes nor pharmaceuticals nor medicinal products, such products being phenol, cresol, aniline, anthracene, etc.—duty 20 per cent ad valorem and 5 cents per pound specific.

The third class should include all colors or dyes derived from coal, including indigo, natural and synthetic, and alizarine—dry or suspended in water—and dyes obtained from indigo or alizarine, and all products derived from coal, which are used for pharmaceutical or medicinal purposes, or other purposes,—duty 30 per cent ad valorem and 7½ cents per pound specific.

Natural indigo and all dyes, pharmaceuticals and medicines, and all other products derived from natural sources of vegetable or animal origin, and which are used interchangeably with similar products derived from coal, should be included in class three.

ANTI-DUMPING CLAUSE. There should be an anti-dumping clause to prevent unfair competition instituted for the purpose of destroying American industry. A dumping clause must be drafted with utmost care and its working tactfully handled. If it be too drastic, or if handled without good judgment, it will become worthless, or worse, because foreign countries, in retaliation, will inflict the anti-dumping penalty upon any American manufacturers who may sell their goods in those countries at lower prices than in the United States. We cannot afford to take any chances with American industry now when our export trade in manufactures is becoming better established than ever before in our commercial history.

COMPULSORY WORKING OF PATENTS in theory looks attractive. In practice there has been nothing in the history of the coal products industry which could have been changed or improved by it to the slightest degree. Compulsory working of patents has been tried in England, France and Russia as recently as 1907, and proven a total failure in those countries.

As stated by the German authority, Prof. Otto N. Witt, "The success of a coal-tar dye factory is no longer dependent upon the careful guarding of factory secrets as in the past, but upon a systematically arranged plant and the proper distribution therein of the work to be performed, and above all upon skillful commercial management, both within and without the factory."

LACK OF TECHNICAL COMMON SCHOOL EDUCATION is a further

disadvantage, from which we suffer. Our system of early 19th century education includes no technical or trade schools, by which in Germany, the entire population is perfected in 20th century methods for earning their living in 20th century industries. In consequence American labor does not give effective attention to its job, and it is extremely difficult to secure labor in the United States which will give competent attention to the delicate chemical manufacturing operations of the coal products industry.

In Summary, the essentials for creation in the United States of a complete industry in the manufacure of products derived from coal are: Co-operation of the American acid and alkali manufacturers with the coal products industry; co-operation of the American consumers with American producers through long-term contracts to assure us the American market; establishment of the industry on a peace scale big enough to make it a fundamental factor in national defense; establishment on a profitable commercial basis of the manufacture of nitric acid, by fixation of atmospheric nitrogen; nationalization, or rather internationalization, of the industry to insure a balanced world market for all by-products; development of a system of 20th century common school and technical school education, and finally maintenance of a rational tariff.

That a larger coal products industry will be established in the United States is certain. The degree to which it attains perfection will be in proportion to the extent with which these requirements for its profitable operation are provided.

H. W. Jordan.

Syracuse, New York,
December 18, 1915.

DISCUSSION

Dr. FRERICHS: My company has been engaged in the manufacture of some coal-tar products for about twenty-five years, such as salicylic acid, oil of wintergreen, etc. In order to give you an idea of the extent of these manufactures, might say that we put out about 600,000 pounds of salicylic acid, 400,000 pounds of oil of wintergreen per year. During all this time we have been obliged to buy carbolic acid from abroad. During the Boer war no carbolic acid could be obtained from abroad and we had to resort to home manufacture. At that time only crude carbolic, and not the finished product, was made here. It was the same case with benzol, which was only produced at that time in the crude state, and which was used only as a solvent and sold as such. At that time an attempt was made to make synthetic carbolic acid, but it failed here for the lack of pure benzol. Synthetic carbolic acid was made at that time in Germany, and could be made at a cost of about 18 cents, but here in this country it could not be made. The price of pure carbolic acid imported was about 9 cents, so it is evident that in normal times the manufacture of carbolic acid was not very remunerative. Am I right in my idea that only crude carbolic acid was made during all this time, and not the pure article?

Mr. JORDAN: Benzol was made at 90 per cent, and such amounts as we required were refined to 100 per cent. The synthetic carbolic which we produced was refined to 100 per cent. The reason we gave up the manufacture of synthetic carbolic acid was because the carbolic acid imported from Germany was sold at price below our cost of production.

NOTES ON A NEW PROCESS OF BLEACHING

By S. F. PECKHAM

Read at the Baltimore Meeting, January 14, 1916

Some years ago a man brought to me some flax fiber and asked me to bleach it by a quick process without injury to the fiber. He said that a certain party that he named claimed to have done it. I said to him: "You have nothing left but paper pulp," and after some talk he owned up that that was the case.

I knew that about thirty years ago one Charles Toppan had taken out a patent for a bleaching compound, of which the fixed oil of mustard and petroleum were the essential ingredients. Great claims were set forth for this stuff, but nothing came of it, as there was too little fixed oil of mustard produced in the world to supply the demands of one large bleachery. At that time the only petroleum on the market was Pennsylvania petroleum, and it was a well-known fact that the crude petroleum and its distillates would dissolve in a solution of soap. A study of this process from all available sources led me to conclude that Toppan's Compound, which was originally a lubricating compound, consists of a fixed mustard oil soap dissolved in petroleum, and that by varying the proportions his bleaching compound consisted of petroleum or its distillates dissolved in a solution of fixed mustard oil soap.

A complete study of the chemistry of the fixed oil of mustard led me to conclude that any other pure vegetable oil soap might act in a similar manner. The cheapest oil soap on the market of that description is what is known as cotton oil soap stock. Having procured some of this I proceeded to make a solution of Pennsylvania petroleum distillate in a solution of the soap. This oil readily dissolved, and on boiling the flax in the solution it came out in the condition to be readily bleached in bleaching solution; but I concluded that the result was not wholly satisfactory, as the bleaching solution had to be so strong or the immersion had to be so long that the fiber was tendered.

I then concluded that I would try all the hydrocarbons on the

market that came within the range of practicability as to price and sufficiency of supply. I first made up a solution of a distillate of California petroleum, and on boiling and bleaching the flax it came out very much better in every respect. Reflecting on the fact that California petroleum consists of benzole and its derivatives, while Pennsylvania petroleums consist of paraffins, the idea occurred to me that perhaps still better results could be obtained by using pure or nearly pure benzoles.

I found that the different benzoles dissolved in soap solution much more readily than the petroleum distillates and that the cleansing effect on the flax fiber was marvelous. Immersion in very dilute bleaching solution produced a perfect dead-white bleach and left the fiber unimpaired in strength. In fact, I had accomplished precisely what the gentleman had asked me to do.

This method can be successfully applied to all vegetable fiber, as linen is the most difficult to bleach of all of them without injury to the fiber.

I have never seen any mention made in chemical literature that benzole and its derivatives are soluble in a solution of soap, nor did I ever hear any statement to that effect. No fixed formula can be designated, as soap is soluble in water in all proportions and the stronger the solution of soap the more benzole the solution will dissolve. The formula I used was for 100 pounds of flax.

Water	50 gals.
Soap	10 lbs.
Benzole	3 gals.

This was used for a heavy woven linen damask, where for ordinary light cottons, such as "gray cloth," very much less material is necessary. It need not be pure benzole, but any of the light distillates of coal tar, coke oven tar or blast furnace tar, freed from impurities by washing and proper treatment.

My invention consists of a process of bleaching by substituting for the usual lime and soda boils a single boil in a solution of soap, perferably a pure vegetable oil soap, in which is dissolved a sufficient quantity of benzole (C_6H_6) or its hemologues or derivatives as found in the light distillates of coal tar and similar liquids and in light distillates of some varieties of petroleum, especially that of California as distinguished from the light distillates of paraffin

petroleums. The strength of the solution in both soap and benzole would depend upon the kind and character of the material to be bleached, light cotton fabrics requiring less than heavier cottons, and any cotton less than flax, jute, or hemp.

After thorough squeezing and washing to remove the soap solution, the goods or fiber may be bleached in any known chemic, but I prefer a chemic of my own invention, consisting of a solution of sodium hypochlorite, prepared by pouring together cold, a solution of 58 per cent soda ash and a solution of calcium hypochlorite, stirring the mixture and allowing it to settle. Both solutions should be prepared cold, and after mixing the solutions they should be allowed to stand at least four days or until all the available chlorine in the calcium hypochlorite shall be found in combination with the sodium and in solution. No formula can be assigned for this mixture, as calcium hypochlorite varies indefinitely in strength. The quantities taken should be such that there should be a slight excess of the sodium carbonate. After a great many experiments upon this chemic I have found this method of preparation, which is very unlike any which is laid down in the books, to be the only one that will bring all the available chlorine in the calcium hypochlorite into solution as sodium hypochlorite. It is better to prepare this solution of a strength 3°-5° Twaddle, and dilute it to such a strength that an immersion of the goods from three to five hours will effect a bleach. After washing the bleached goods in water they are soured, washed and calendered as usual.

By this method a complete bleach of either cotton or linen can be had in from one to two working days.

I have described a process of bleaching by which the goods or fiber are prepared for the chemic by boiling in a solution of soap in which has been dissolved a sufficient quantity of benzole or its hemologues or its methylated derivatives, either separately or mixed together, as found in coal-tar naphthas and similar liquids and the distillations from some petroleums as above set forth.

The soap which I have used is the cheapest that I know of on the market, as it is a by-product of the refining of cotton seed oil and is used in its crude state without further treatment.

The apparatus used is a Kier with a steam jacket to which is attached an inverted condenser, which returns the evaporated hydrocarbons to the Kier. The process was applied on a small scale and thoroughly tested out with the most gratifying results. Of course

the goods are singed and sheared, as is customary. Goods in small pieces were digested for various periods of time and the resulting goods subjected to a great variety of tests excepting the effects of time upon finished goods. It was found that if the goods were thoroughly dried after thorough washing to free them from soap the effect of the chemic was very much more satisfactory than when they were introduced into the chemic damp, directly from the squeezers. This is not surprising when very dilute solutions of chemic are used as the water remaining in the goods from the squeezers not only diluted the chemic still further but filled the pores of the goods, thus getting in the way of the chemic and preventing it from doing its work.

An application was made for a patent with the confident expectation that a valuable invention had been perfected, but the officials at the Patent Office in Washington quoted Toppan's and other patents against me, and I found that no amount of argument would convince them that there was the slightest difference between the substances designated "Benzine" and "Benzene," in fact they declared they were identical. Comment is unnecessary in this place upon such a highly scientific administration of the patent laws.

LUTES AND CEMENTS

By S. S. SADTLER

Read at the Baltimore Meeting, January 14, 1916.

I use the words *lutes* and *cements* together for two reasons: First, because they have different meanings, the former referring to temporary applications and the latter to more permanent uses. Second, the use of these words conjointly shows to a casual reader that the subject of this paper is not solely with reference to Portland cement.

Quite a few years ago I read several papers on the present subject. In these papers I classified the formulæ according to composition in one instance and according to intended use in another. These papers were noticed by a number of people who communicated with me, particularly engineers.

It is very difficult to give proper credit for what one finds in the literature, as some of these formulæ are like humorous stories that are rarely traceable to a source. In looking up this subject for the present occasion I noticed some eight or ten attractive formulæ in a well-known handbook of Industrial Chemistry. These were credited to a periodical which I soon found quoted one of my papers and I was not the originator of more than a few of them. Thus, things are passed on. The value of the formulæ was diminished, however, by reason of the space allotted and changes.

I will classify the formulæ now, as I did before the Engineers Club of Philadelphia, by the use of the following subdivisions. Very few of the formulæ given herewith have not been tried by me. The only instances are where the authority was excellent and adequate trial was not practicable for some reason.

1. WATERPROOF: Of the chief bituminous substances available we have pitches, asphalts, Gilsonite and blown petroleum residues, mixtures of these substances and mixtures of the same with inert oils and material.

Of the asphalts I prefer a substance like refined Bermudez, as it is nearly pure bitumen and forms homogeneous solutions with suitable solvents. A minor percentage of boiled linseed oil or

blown petroleum oil is useful sometimes for tempering or fluxing. For solvents, heavy naphtha is generally used. It does not dissolve all the asphalt, such as the so-called asphaltene portion, but it thins out the asphalt well enough. Coal-tar naphtha is better but more costly. As voids are very apt to form in a painted asphalt coating, some form of filler is generally employed, either by coating paper so that it becomes more or less impregnated or by the addition of a filler, such as silex, infusorial earth, etc. The natural mineral filler of Trinidad asphalt may serve the purpose of such filler.

For a soft water-tight coating in cement work, blown asphalt and infusorial earth, thinned with a solvent, such as heavy naphtha, is desirable.

The use of blown asphalts with natural asphalts and Gilsonite is in some cases desirable, as these products are ideal fluxes for hard asphalts and tend to prevent brittleness or separation of the films when the solvent evaporates. The harder or higher melting point grades of these blown residuums are capable of making good cements alone or with filler, but are rather hard to dissolve. Such artificial asphalts have melting points as high as 150° C. whilst the softer ones that are probably best for fluxing have melting points about 80° C.

Lutes of boiled linseed oil, thickened with clay, asbestos, red or white lead, etc., are waterproof, if thick enough from the filler added.

Flaxseed meal made into a stiff paste with water is useful as a lute for steam connections and is easily applied.

Portland cement only serves as a waterproof cement when given time for the preliminary setting to take place. It is not generally impervious to water and because of its colloidal character while setting it seems hard to realize that it could ever act other than as a water pervious diaphragm. But when fully or reasonably well set and dry the colloid character no longer exists and does not return to these particles that have taken part in the setting from hydration.

For all practical purposes the use of trade preparations, such as those containing metallic soaps or oil emulsions, serves to render concrete approximately impervious, but I will refer to a few points I have noticed in making or using lutes and cements.

For making small experimental electrolytic cells, etc., for demonstration purposes, I have found it desirable to use white

iron-free Portland cement and white plasterer's sand that had been sieved. If a one to two mixture is made with the prescribed quantity of an approved waterproofing substance, such as the product of the Newberry patents, and care is taken to work out voids and the article in the *green* is kept moist, a very nice waterproof container can be made. It will also stand dilute acids or alkalies but not the two alternately. For large articles wire mesh reinforcement is often desirable and if the vessel is used for dilute acids this might well be made of a mesh of Monel metal, etc.

In the literature on this subject, if it can be dignified by that appellation, one finds frequent reference to making lutes with Portland cement and silicate of soda. Some of these may work and others will not and I approach them with caution. A little silicate of soda in the water will help towards a quick initial set, for instance, for under water work. Water containing 4 to 20 per cent of silicate of soda by volume causes a preliminary set in two hours that prevents washing away by water. It affects the natural and gradual hydration unless the soluble salts resulting from the reaction are washed out by excess of water, which is difficult to do. Mixtures containing above 4 per cent of silicate show strong efflorescence, which is particularly marked with that made with 20 per cent aqueous solution of silicate in the water. The silicate of soda setting is at first due purely to double decomposition of sodium silicate and calcium hydroxide. If very strong silicate is used the mass stiffens so fast that it cannot be worked. This is true of all concentrations above 50 per cent. There is one point that might be noted. For immediate immersion in running water, silicate of soda acts as a binder, while the particles of the cement form gelatinous colloids instead of being washed away. The soluble sodium salts are more or less eliminated and apparently normal concrete results. I have used glue solutions (3 to 5 per cent strength) with white Portland cement to secure very dense compositions. It is possible that the glue aids colloid formation and protect the same against too rapid crystallization.

2. Oil Proof: (*a*) Several of the best known lutes I am placing under this category, although they might be classified elsewhere.

	Parts by Weight
Good glue	2
Glycerine	1
Water	7

The glue is first softened by the water, then liquefied by heat and the glycerine incorporated. This is a good lute to render corks vacuum tight, for stopping small leaks of almost anything except water and steam.

(*b*) The following has been found useful in laboratories and in the works for oil vapors:

Putty of molasses and flour.

(*c*) The next lute to be mentioned is one of the best known and most useful. The proportions given are those I have found satisfactory.

Glycerine ..... 90 parts by volume
Water ..... 10 " " "

to be made into a stiff putty with

Litharge ..... 90 parts by weight
Red lead ..... 10 " " "

It takes several hours to stiffen and about a day to set.

(*d*) Several cements of which silicate of soda is an active principle or the chief binding substance are made as follows:

Silicate of soda ..... (about 30° Bé)
Whiting
Made into a stiff putty.

This slowly sets by drying if not by chemical action. If magnesium carbonate be used the setting is so quick that it is hard to use the mixture. If magnesium carbonate be used the silicate should be diluted to one-third to one-half normal strength. I do not recommend either of these formulas.

(*e*) Barium sulphate is often used with silicate of soda. The silicate should be about 30° Bé. If the mixture is heated by a preliminary heating of the silicate or it is put in a hot place there seems to be some chemical reaction which aids in the setting.

(*f*) A very strong and ultimately hard cement or substance for a variety of purposes is made by incorporating glue with plaster of Paris. This will be described with other plaster plastics in section 5.

3. Acid Proof: (*a*) The asphaltic preparations referred to in

Section I are largely acid proof. Black putty, the formula for which was first noticed by me in a Handbook of Chemical Engineering by Geo. E. Davis, is made by intimately mixing equal weights of China clay, linseed oil and gas-tar. The ingredients must be anhydrous, so it would probably be best to take a tar residuum or very soft pitch or thick, so-called, creosote oil. Rubber cements may have varied composition, but I will only refer to two, which are, perhaps, extremes. If equal parts of fresh unvulcanized rubber are used the mass is so stiff that it would be probably used alone. If as much as four parts of linseed are used considerable filler can be incorporated and make a workable putty.

(*b*) Equal weights of rubber and boiled oil are taken; the rubber is first dissolved in carbon disulphide in the proportion of 4 cc. carbon disulphide to 1 gram of cut-up rubber. Boiled linseed oil is then mixed and the mixing is facilitated if the oil is warm. The solvent is generally not removed by evaporation until the paste is applied.

(*c*) The other formula, to which reference has just been made, differs in having four times as much boiled linseed oil and then fire-clay or other filler, such as silex, is used.

Crude finely cut rubber	1	part by weight
Linseed oil, boiled	4	" " "
Fire-clay	6	" " "

(*d*) Melted sulphur with fillers of stone powder, cement, sand, etc., are used. The following is used for hydrochloric acid vapors:

Rosin	1	part by weight
Sulphur	1	" " "
Fire-clay	2	" " "

Linseed oil (boiled) and fire-clay stand most acid vapors.

(*e*) According to Davis, red lead and litharge in boiled oil stand acid vapors (even nitric acid).

Litharge	80 lbs.
Red lead	8 "
Flock asbestos	10 "

fed into a mixer, a little at a time, with 6 quarts of boiled linseed oil.

There are numerous acid-resisting mixtures possible, in which silicate of soda is used. This is possible, in spite of the strong basic character of silicate of soda, because the silicate is superficially changed to colloidal silica, which continues the cementing work, at first affected by the silicate of soda.

(*f*) Barium sulphate, powdered glass, China-clay, etc., are used with silicate of soda slightly diluted with water. A strength of about 30° Bé. is close to what is best for the purpose.

(*g*) The following I have used with success for dilute hydrochloric acid:

White China-clay	1 part by volume
Fine white sand or powdered quartz and sand	2 " " "

are mixed thoroughly and worked up with just enough silicate of soda, diluted with an equal volume of water, to make a paste. This can be rendered more impervious to water by the judicious incorporation of organic colloids. If a little fine casein be incorporated with the silicate of soda in a mixer so that the mixture is quite smooth the mass will be tougher. About 5 per cent of fine, dry casein powder is added, based on the weight of silicate. If fresh milk curd can be used, corresponding to the same dry weight of casein, and allowance is made for the water contained, a mechanical mixer may not be needed.

4. Chlorine Resistant: (*a*) The most reliable are made with Portland cement as chief ingredient:

Powdered glass	1 part
Portland cement	1 "
Silicate of soda	1 "

The last mentioned should be diluted considerably so as not to set too fast.

Portland cement quickly reacts with silicate of soda, but powdered glass and clay react more slowly with silicate of soda and finally render the cement insoluble as regards its mass.

5. General Purposes with Plaster of Paris: This series of lutes and cements is highly important and individual formulæ will serve to prevent the escape of hydrocarbon and other gases in furnace work, as cements for mechanical purposes and as coatings,

such as plaster, when mixed with asbestos straw, plush trimmings, hair, etc.

(*a*) Soluble sulphates form double sulphates with calcium sulphate and with water. They set harder and are more impervious than calcium sulphate (plaster of Paris) alone. It is desirable not to take equal molecular quantities to form the full double sulphates but about half of these quantities of the added sulphates. Sodium, potassium and aluminum sulphates are used for this purpose.

(*b*) According to Sigmund Lehner, a little borax in the water used makes hard cements and regulates the setting:

12 volumes water to 1 vol. saturated borax solution sets in 15-20 minutes at 10° C.
8 " " " 1 " saturated borax solution sets in 1 hr.

The same author gives a formula credited to Viotti for a weather-proof plaster cement.

(*c*) 1500 grams of borax and 150 grams of magnesium oxide are melted together and powdered. This powder is then mixed with 75 grams of plaster of Paris. Borate of magnesium thus predominates and protects the plaster from being washed away by water.

6. Marine Glue: A standard preparation of this class of lutes (which are applied to crevices, etc., hot, and get firm but not brittle when cold) is composed as follows:

Crude rubber	1	part	by	weight
Shellac	2	"	"	"
Pitch	3	"	"	"

The rubber is first dissolved in carbon disulphide or turpentine before mixing with the heated (not superheated) mixture of the other two. The advent of blown petroleum residuums has made it possible to make up hard but flexible compounds without rubber. Grahamite is a good base to which fluxes, such as these just mentioned, or soft asphalts, are added.

7. Gasket Compositions: There are so many good gasket compositions on the market that I was on the point of omitting all reference to them. For factory work I have found no trouble in getting ropes of graphitized asbestos, rubber composition, leather fibers cemented with rubber, etc., that are quite satisfactory.

In the laboratory, one can generally make out for low temperatures and pressures by saturating heavy "kraft" wrapping paper with soft pitch, such as wood pitch for steam or with gelatine and glue (hectograph) composition for oils. For high pressures, slots filled with lead rings and V-shaped rim to the lid are most satisfactory.

8. MACHINISTS' CEMENTS: A few words might be said here with reference to machinists' cements. These are the well-known red and white leads. The red lead is often diluted with an equal bulk of silica or other inert substance so as to make it less powdery on drying. The best way that I have found to do this, however, is to add rubber or gutta-percha to the oil as follows:

Linseed oil	6 parts by weight
Rubber or gutta-percha	1 " " "

The rubber or gutta-percha is dissolved in sufficient carbon disulphide to give it the consistency of molasses, mixed with the oil, and left exposed to the air for about twenty-four hours. The red lead is then mixed to a putty. Oxide of iron makes less brittle cements than red lead.

9. LEATHER CEMENTS: As cements of this class are apt to be wanted by chemists sometimes, I quote from my paper in the Transactions of the Engineers Club of Philadelphia, XXI, 4, 1904.

The following formulæ are given in the "Papier Zeitung," Vol. 18, p. 2618:

"(*a*) Equal parts of good hide glue and American isinglass, softened in water for ten hours and then boiled with pure tannin, until the whole mass is sticky. The surface of the joint should be roughened and the cement applied hot.

"(*b*) One kilo of finely shredded gutta-percha digested over a water-bath with 10 kilos of benzol, until dissolved, and 12 kilos of linseed oil varnish stirred in.

"(*c*) Seven and one-half kilos of finely shredded india-rubber are completely dissolved in 10 kilos of carbon disulphide by treating whilst hot, 1 kilo of shellac and 1 kilo of turpentine are added, and the hot solution heated until the two latter ingredients are also dissolved."

(*d*) Another one noticed in the "Journal of the Society of Chemical Industry":

Gutta-percha	8 ozs.
Pitch	1 oz.
Shellac	1 "
Olive oil	1 "

These are melted together.

10. Iron Cements: When iron in a fine state of division, as in fresh oil-free filings or cast-iron borings that have been powdered, is mixed with an oxidizing agent, such as manganese dioxide or a substance electro-negative to iron, such as sulphur, in a good conducting solution like salt or salammoniac, galvanic action sets in very rapidly, ammonia is given off (if salammoniac be used) and the iron expands, by forming iron oxide, and cements the mass together. It is best diluted with Portland cement. A formula which I give from memory is:

Iron filings	40 parts
Manganese dioxide, or flowers of sulphur	10 "
Salammoniac	1 "
Portland cement	20 to 40 "
Water to form a paste.	

These cements are used extensively in foundries, etc.

I prefer manganese dioxide to sulphur as a negative element. The free carbon of cast iron that has been powdered is negative pole enough to react, but the use of manganese dioxide causes quicker action. If not diluted with cement they are apt to expand too much and bulge out from the hole or crevice in the iron.

11. Crucible Cements: (*a*) Mixtures of clay and borax in which the clay predominates. Silicate of soda and powdered glass or sand are the best known compounds for cementing lids on crucibles, etc. Sometimes the "iron cements" are used for such purposes, or iron filings and a little manganese dioxide are added to the above compositions for crucible cements.

(*b*) Probably the best known cement for graphite is fire-clay; which, with water, binds the graphite fairly well and itself stands high temperatures.

(*c*) In some cases it is desirable to have an all carbon binder, and for this purpose tars or soft pitches are used. Very little binder must be used, however, or the material will crack when heated, as the carbonizing of the pitch shrinks the binder somewhat.

Starch paste has been recommended for this purpose, but the shrinkage is greater and the binding is not as good.

(*d*) A strong, waterproof cement that will stand high temperatures may be made by mixing powdered silica or fine sand and powdered silica with a solution of magnesium chloride of about 10 per cent strength. This composition is applied as a putty and then painted or soaked in a solution of silicate of soda of about 30 per cent strength. This forms magnesium silicate as a binding material for the silica.

12. MAGNESIA COMPOSITION FOR FURNACES, ETC. Magnesia burned at incandescent heat or hard burned—80 per cent. Magnesia light burned (just sufficient to drive off carbon dioxide (dull redness) 20 per cent. The composition is made into a stiff putty with water and shaped as desired. The water must be driven off very slowly. A small proportion of good asbestos fiber may be worked in to keep from cracking.

13. OXYCHLORIDE CEMENTS: These are sometimes called stone cements and the only one of practical importance is that made with magnesium chloride.

If the magnesium chloride is quite pure, i.e., free from potassium or calcium chloride, the solution used need not be more than 18° Bé., but if German magnesium chloride be used it requires a solution of 20 to 22° Bé. The magnesium ovide must be freshly burned at a dull red heat, as the light oxide that is requisite for this cement readily absorbs carbon dioxide from the air and becomes unsatisfactory or of no use for making cement compositions. A diluent for the magnesium oxide is generally used, such as silica or wood pulp, ground wood, etc.

DISCUSSION

Sec. OLSEN: I did some work myself on iron cements, and found that the size of the iron particles has a very important bearing on the setting and hardness of the cement produced. I was very much surprised. Unless you pay attention to the size of the iron particles you will have a very different kind of material.

Mr. RIEDERER: As an acid-resisting lute one very satisfactory product is Bakelite varnish and asbestos, the only difficulty being that it takes a few days to dry sufficiently to resist hydrochloric acid and chlorine, moist or dry.

THE DESIGN AND OPERATION OF OZONE WATER-PURIFICATION SYSTEMS

By SHEPPARD T. POWELL*

Read at the Baltimore Meeting, January 14, 1916

Although the first attempt to purify water on a practical scale by means of ozone was made less than thirty years ago, still this gas was generated and its chemical and physical properties were studied by many investigators for more than a century. In all probability ozone has been recognized by scientists since the earliest ages, if not by name at least by its characteristic properties. The first authentic record that we possess of the manufacture of this gas was in 1783, when Van Marum, a Dutch scientist, termed it " a smell of electricity," as a result of its production by this means.

It was not, however, until the exhaustive studies of Shoenbein, in 1840, that the active properties of ozone were well understood, or any analytical methods were devised for measuring this gas. Shoenbein recognized this active oxidizing agent as a distinct gas to which he gave the name of ozone.

For more than fifty years after Shoenbein's researches nothing was accomplished in placing ozone within the scope of a commercial possibility, although its active and oxidizing power was well known. With the development of the alternating current generators and transformers, which so materially reduced the cost of production, and the increasing knowledge of the bacteriology and chemistry of water ozone was recognized as a water purification agent of great value. Berthelot, a French chemist, in 1890, undertook, with some degree of success, to apply this method of water purification, and from then on Europe, as well as America, has been practically flooded with numerous designs of generators and patented appliances for water treatment.

All the ozonizers that have been devised are based upon the same

* Chemist and bacteriologist of the Baltimore County Water and Electric Company, 100–102 West Fayette Street, Baltimore, Md.

general principle, viz., the production of the allotropic form of oxygen, O_3, from the oxygen of the atmosphere. This is accomplished by passing a current of air over a brush discharge which takes place between the electrodes connected to a high voltage alternating current circuit, and which usually have a solid dielectric interposed between the electrodes.

There are, of course, many other ways of generating this gas, but none of these processes other than the one described has proven a commercial success.

Numerous theories have been advanced to account for the production of ozone in this manner, but the one generally accepted is based on the theory of molecular motion.* This theory, as stated by Dr. C. P. Steinmetz, regards the chemical effect of all ether radiations recognized by light, heat and electrical waves as more or less specific for various compounds to definite frequencies of their movement, setting up resonance effects upon the natural molecular or atomatic motion.

Ozone when pure is colorless, has a distinct and peculiar odor and instantly decomposes at 260° C. It can be liquefied by a pressure of 1840 lbs. per square inch, and at a temperature of −103° C. In this condition it is highly magnetic, but is not so powerful an oxidizing agent as the gas.

The great affinity of ozone for organic matter renders it peculiarly suited for water purification, in that it not only removes the bacteria by direct oxidation, but will eliminate to a considerable degree other organic substances contained therein.

All ozonation plants for the purification of water consist of two distinct parts—the ozone generator and the mixing chamber or emulsifier. If the design or operation of either appliance is a failure, then the failure of the system as a whole is a certainty, as the success of the plant depends equally upon both parts.

It would be impossible at this time to give even a description of the numerous designs of all ozonizers that have been introduced within the past few years, but a brief description of a few of the more important types may be of interest.

THE SIEMAN-DEFRISE SYSTEM. The Sieman-DeFrise ozone generator, which has proved a commercial success at the St. Maur plant for the purification of the water supply of Paris, is shown in

* *Engineering News*, April 28, 1910, Vol. 63, No. 17, page 488.

Fig. 1. The generator consists of an iron box divided into three sections by horizontal metal plates, having the center compartment pierced by glass tubes which are made watertight, so that there is a water jacket above these tubes. Within these glass cylinders are placed aluminum tubes of smaller diameter, so that there is an annular space of about $\frac{1}{16}$ of an inch between the surface of the

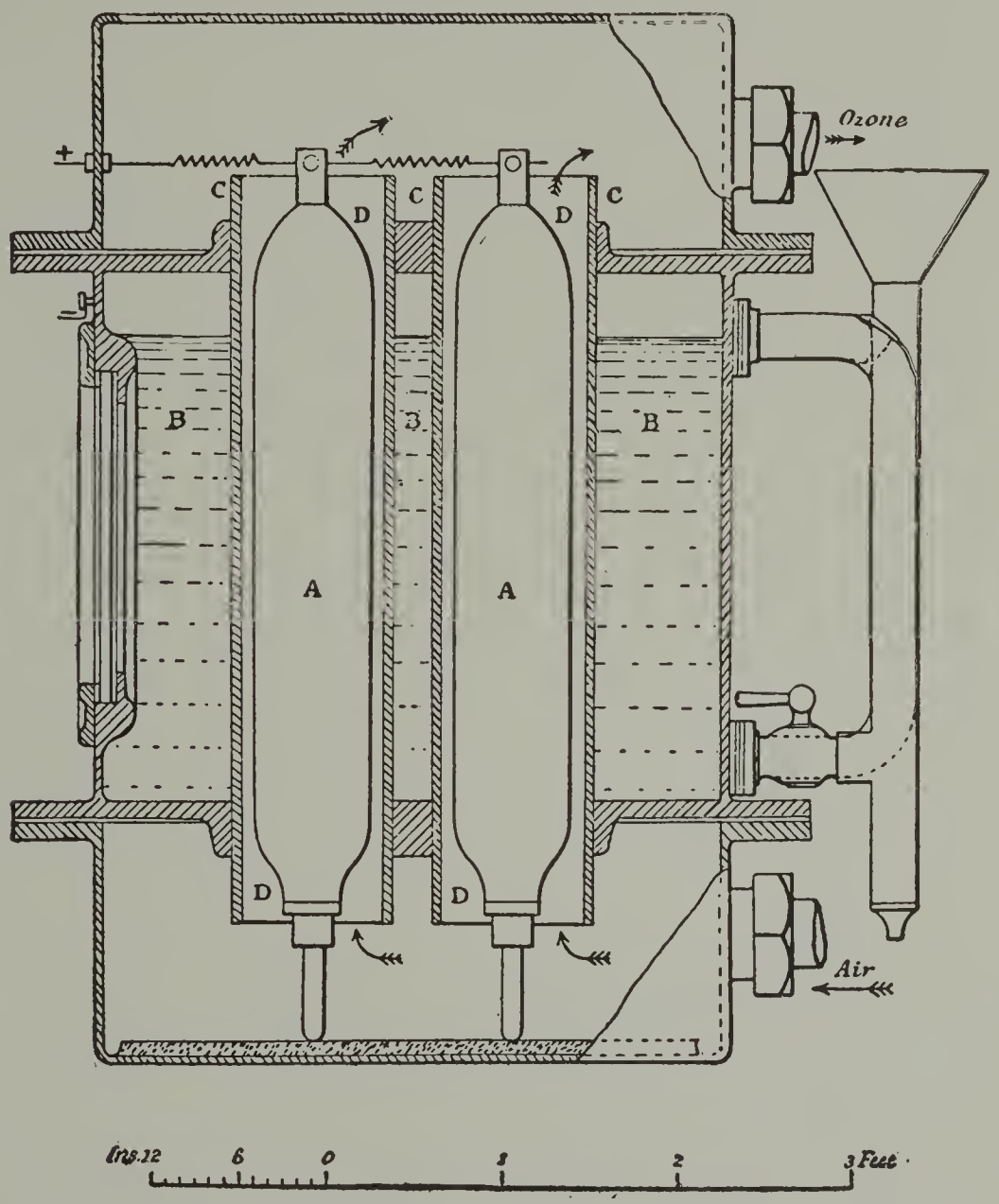


FIG. 1.—Sieman-De Frise Ozone Generator.

electrodes and the dielectric. The aluminum tubes are thoroughly insulated in a metal case, and are connected to a high tension circuit, and as the case is grounded the brush discharge is given off from the aluminum electrode. Under these conditions the oxygen of the air drawn through the tubes is converted into ozone. The ozone is drawn off from the top of the generator by means of a pump and is then forced into and mixed with the water to be treated in

a tower designed for this purpose. Each generator contains eight tubes, and the voltage used is said to be between 36,000 and 40,000 volts.

The mixing or sterilizing tower, Fig. 2, is cast iron lined with enamel, and is 25 feet high and 1 foot in diameter. Within this

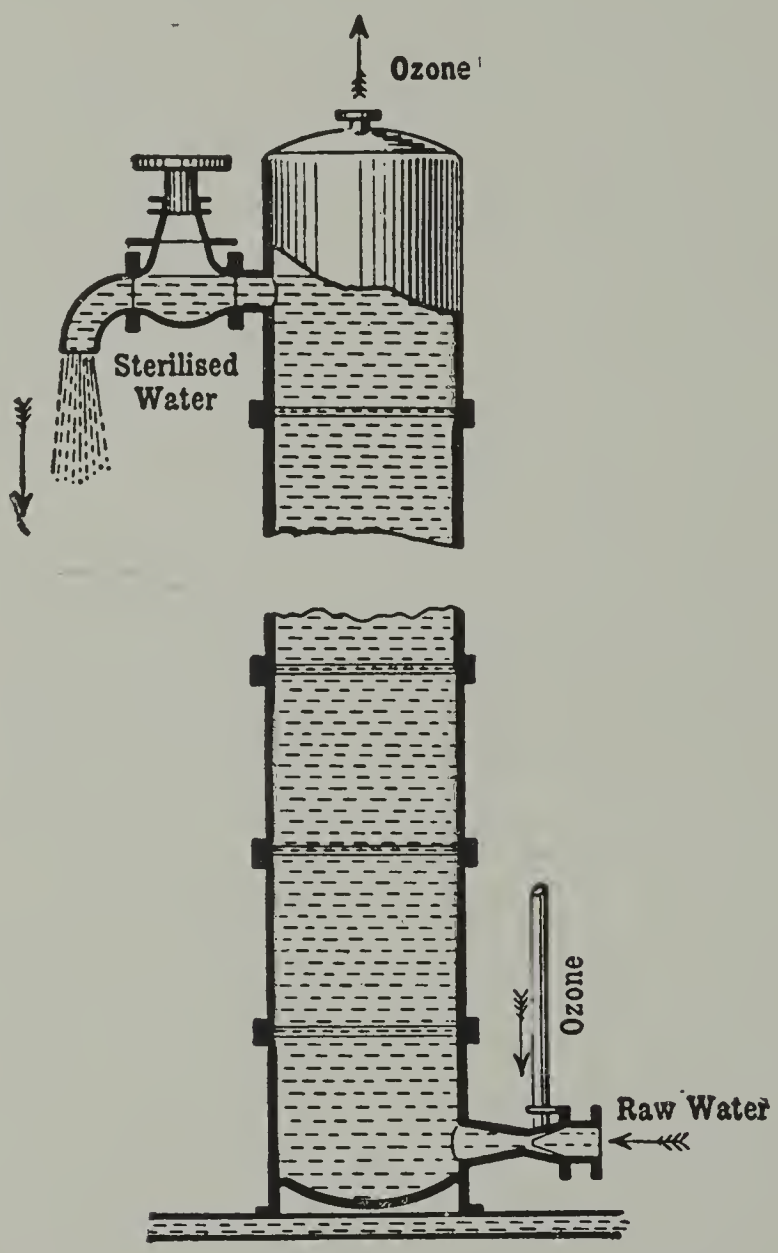


FIG. 2.—Section f Sterilizer.

tower is a set of perforated celluloid discs for the purpose of thoroughly mixing the gas and water.

Dr. Samuel Rideal, in 1908, approved of this system and pronounced it a thorough success, not only from a bacteriological standpoint, but on account of the high reduction of organic matter, which was over 40 per cent as measured by the required oxygen tests.

The general arrangement of the generators and mixing tower of the Sieman-DeFrise system is shown in Fig. 3.

THE VOSMAER SYSTEM. The Vosmaer system as originally designed was unique in that no solid dielectric was used. This type of generator, although a failure from the standpoint of efficiency, is of value to the engineer in designing the generator in that it has proved, even to the mind of the originator, the futility of building an ozonizer without the use of a solid dielectric medium interposed between the electrodes.

This generator, as described by Don and Chisholm,* consists of iron tubes provided with strips of metal fused along their length inside and insulated on porcelain supports. The width of the strips was such that the free edges did not reach the central line toward which they were directed. These edges were cut saw-shaped and each strip was connected to one pole of the high tension transformer, while the tubes were connected to the other pole.

THE OTTO SYSTEM. The Otto system, which was used in ozonizing the water supply at Nice, France, differs quite materially from the other systems that have been described. This generator is composed of a series of metallic plates upon which is coated a metallic foil. In each pair of plates a different potential is maintained and the plates are so spaced as to generate a maximum concentration of ozone by the electrical discharges as the air is drawn through the space between each pair of plates, Fig. 4. A feature of this system is a sterilizing chamber where the ozone is thoroughly and efficiently mixed with water.

THE GERARD OZONIZER. The Gerard ozonizer, although based upon the same general principle as the other types, has an additional feature in that the stream of air during the process of ozonization is subjected to the electrical discharge twice instead of once. This is accomplished, Fig. 5, by drawing the air down the inside of the tubes and back again through the annular space between the inner and outer set of electrodes. These tubes are of glass with tinfoil coated upon them, and are housed in a sheet-iron box on top of which is a marble slab; over the slab is an aluminum case having a glass top, so that the discharge can be seen at all times. The ozonized air is mixed with water by a spraying system, Fig. 6, permitting of three separate applications by means of chambers in the mixing

* Don and Chisholm, 1913, page 219.

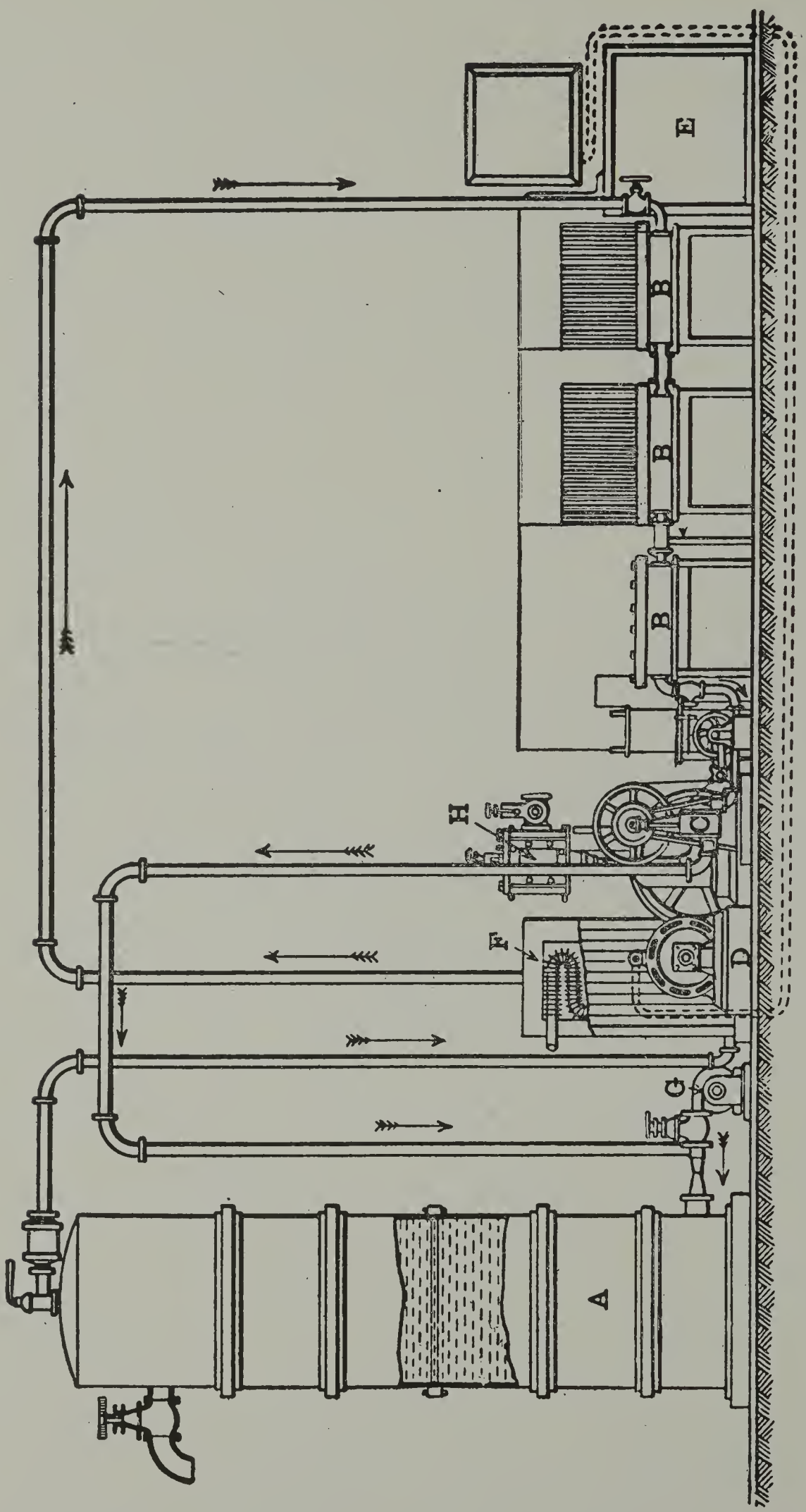


FIG. 3.—Generators and Mixing Tower of the Sieman-De Frise System.

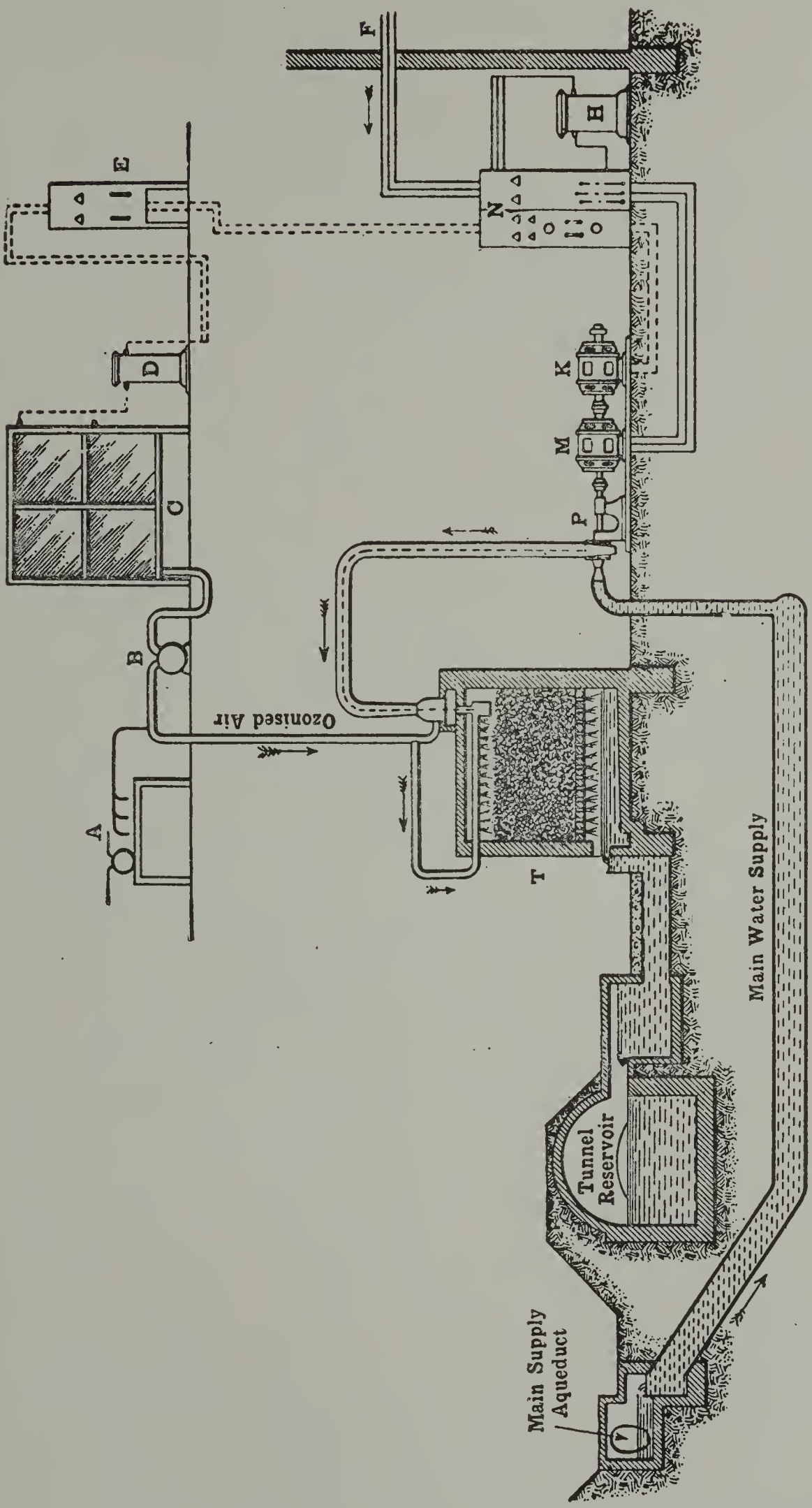


FIG. 4.—The Otto Water Ozonizing System.

device. The air used in these generators is treated by refrigeration and the generators are cooled by oil, Fig. 7.

THE HOWARD BRIDGE SYSTEM. In the Howard Bridge system aluminum electrodes and micanite dielectrics are used, and are of either the cylindrical or flat plate design. The plant built at Lindsay, Canada, was constructed of flat plates, while the Ann Arbor (Michigan) and the Herring Run (Maryland) plants made use of the tubular design. A feature of this original patent consisted in per-

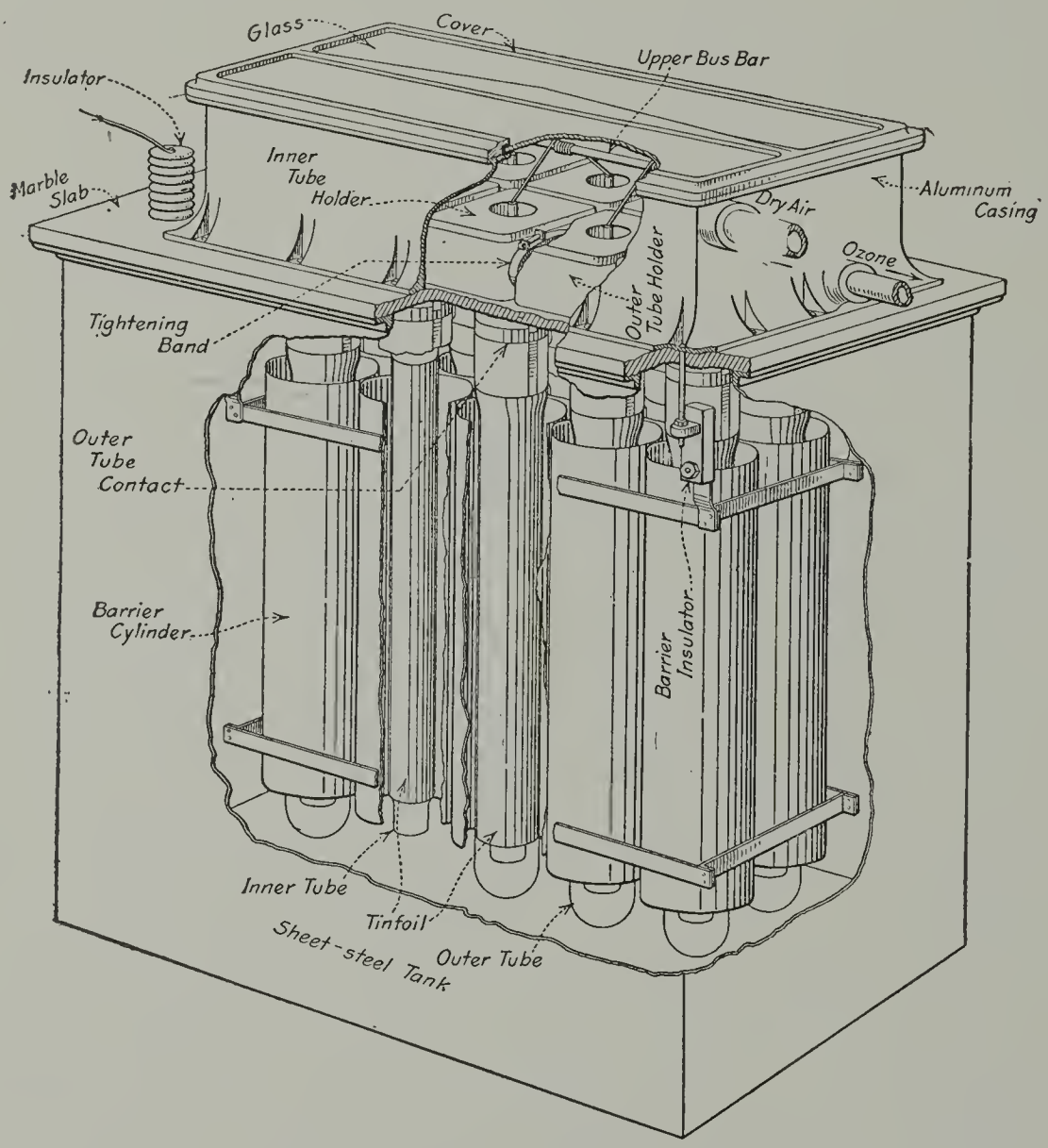


FIG. 5.—The Gerard Ozonizer.

forated electrodes, the object of which was to increase the output by bringing the air into more intimate contact with the brush discharge; theoretically to have each jet of air as it was drawn through the perforations completely surrounded by the discharge. Also the air is not forced into the ozonizers, as is the procedure at the majority of plants of this character, but is aspirated through the

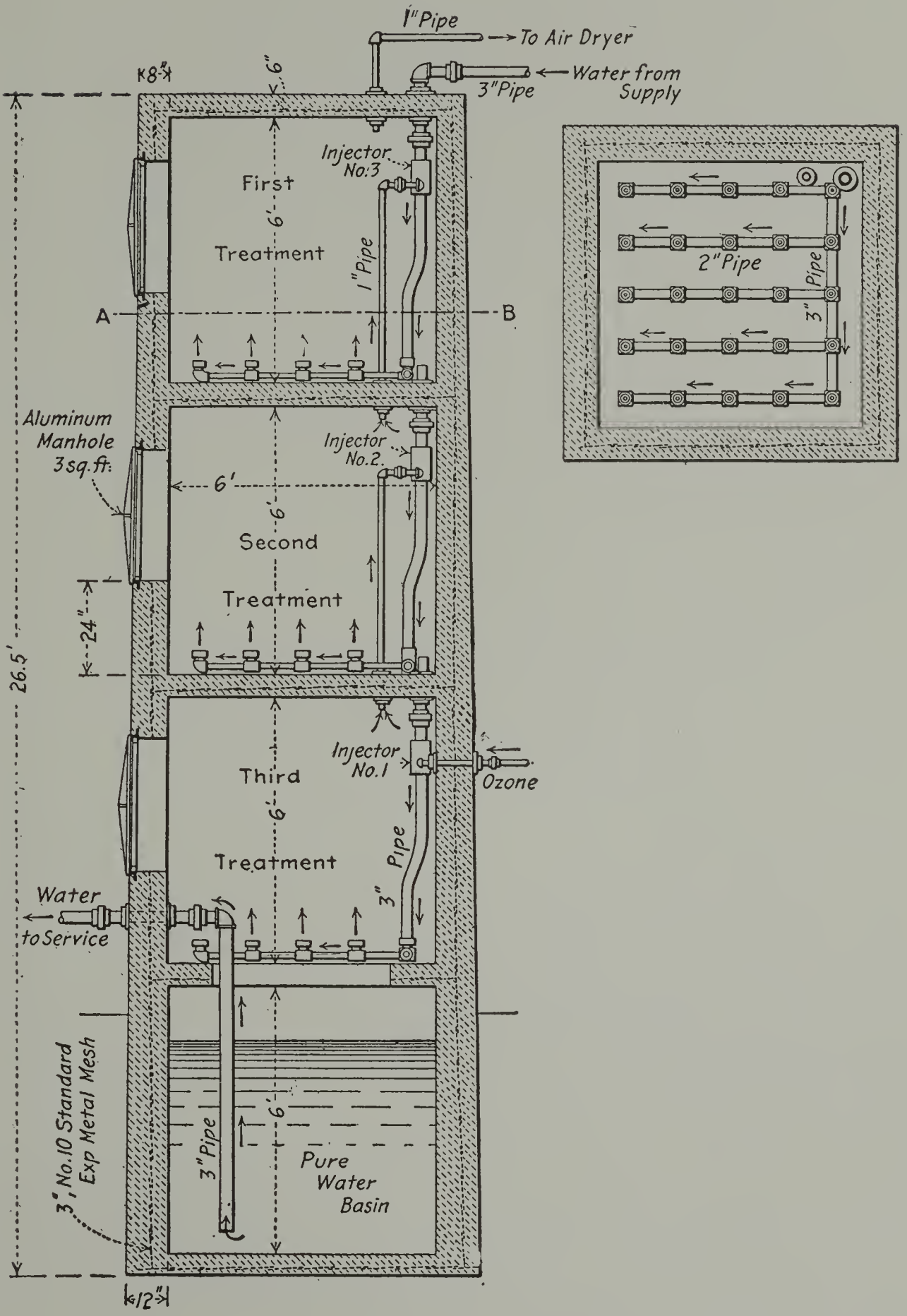


FIG. 6.—Water Treatment System.

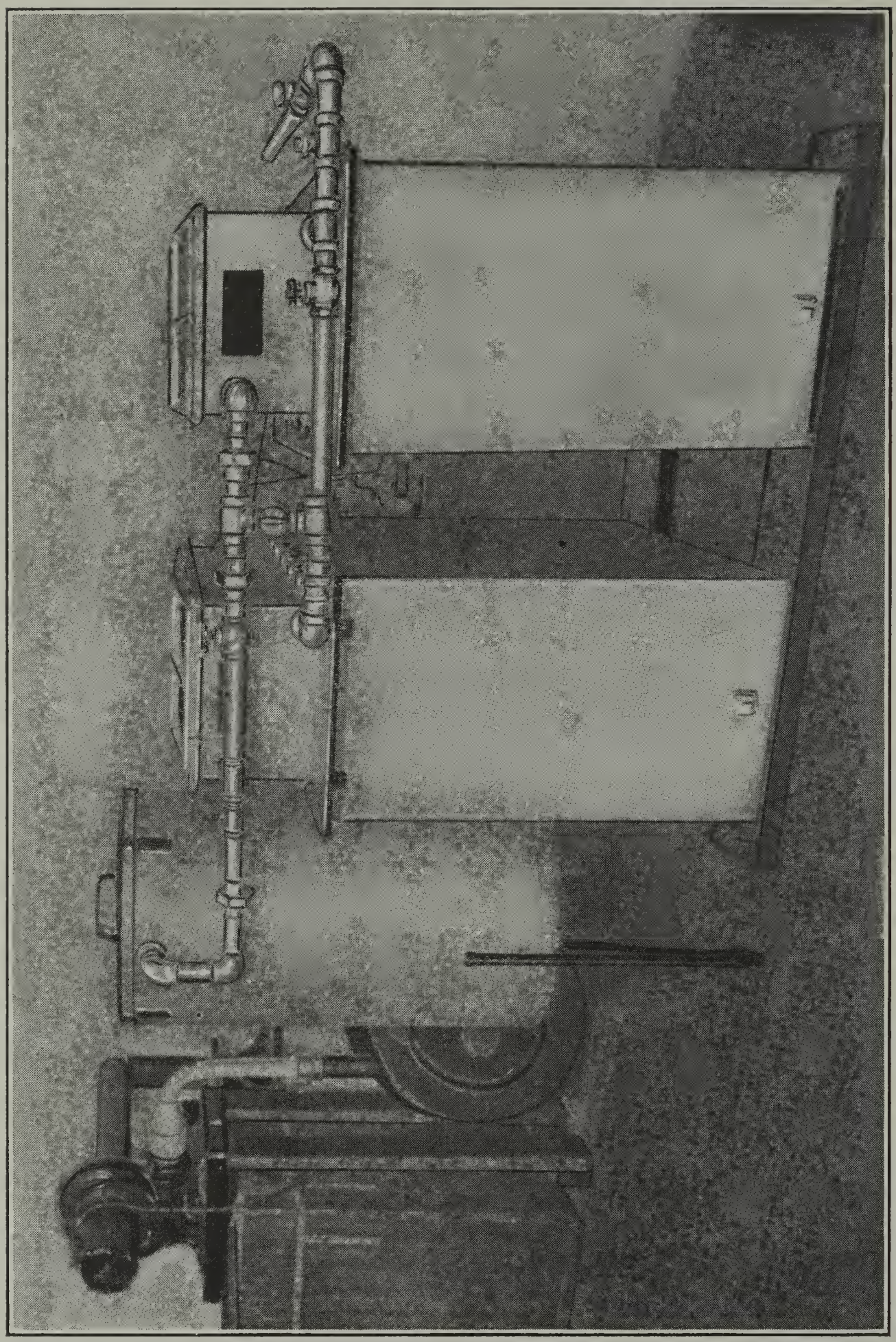


FIG. 7.—Ozone Generators Cooled by Oil.

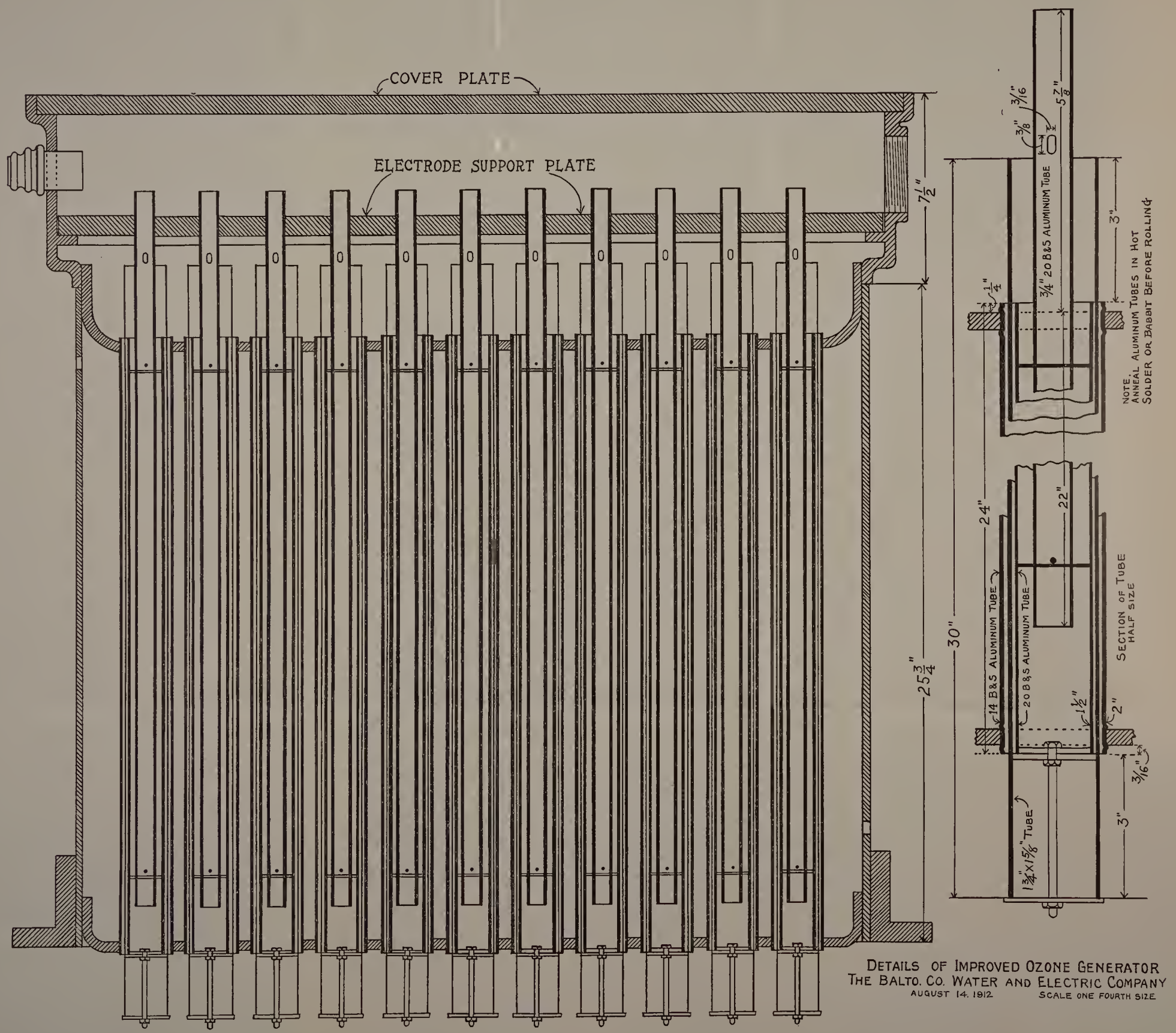


FIG. 8.—Ozone Generators of the Baltimore Co. Water and Electric Co.

To face page 243.

generators by means of the raw water flowing through specially designed nozzles; the object of this is to reduce the cost of pumping the ozone into the water and to obtain a more intimate mixture as the ozone is drawn into the aspirator tubes.

The Herring Run plant was originally constructed under the Bridge patents, and similar in design to the plant at Ann Arbor. Owing to certain minor defects and to local conditions this plant was not a success, so it became necessary to re-design the system. The plant at Herring Run as it exists to-day, although it embodies the general features of the Bridge design, has many additional features as a result of the experimental work carried on by the Water Company under the supervision of Mr. A. E. Walden.

The generators proper are cylindrical iron drums 33 in. high by 36 in. in diameter, within which are 109 aluminum tubes, Fig. 8. These tubes are rolled into the head of the drum in much the same manner as the tubes in a tubular boiler, so as to be watertight. Within these tubes are micanite dielectrics, and within the dielectrics are another set of aluminum electrodes. The case of each generator is connected to one pole of the transformer and is grounded, while the inner electrodes are connected to the other pole. Discharge takes place between the electrodes and ozonizes the air as it is drawn through the annular spaces on either side of the dielectrics. The air is refrigerated and the drums are cooled by artesian well water. The ozonized air is sucked through the generators by means of the aspirators, and delivered to the bottom of the mixing well.

The Herring Run plant is quite flexible in operation and has demonstrated the fact that ozone generators can be so constructed to be capable of continuous operation under varying atmospheric conditions for long periods without serious breakdowns.

It might be of interest to state briefly the reason for the particular character of dielectrics and electrodes that have been used in the construction of these generators.

It is well known that many other metallic electrodes could be used in place of aluminum, at a much less first cost; aluminum, however, is the only metal of which we are aware, other than gold or platinum, that will withstand the corrosive action of the ozone. Vosmaer and others have claimed that the choice of material for electrodes is immaterial, but this is contrary to our experience during the past six years. The main objection to the use of aluminum

for this purpose is that sooner or later aluminum nitrate is formed upon the surface of the tubes, and as this compound is deliquescent it creates disastrous arcs. This condition, however, can be overcome by removing the electrode and cleaning the surface. The production of nitrate on the electrodes would indicate that some nitrous compounds are formed, and undoubtedly this is so, but from careful tests we have not been able to determine this, so the quantities formed must be infinitesimal.

A number of dielectrics of various materials were tried, but up to the present time none of them has, under actual tests in this particular generator, proven as satisfactory as the micanite tubes in use. The objection that has been raised against the use of micanite is that under continuous use the mica sheets separate, causing unevenness in thickness. It has been demonstrated in our experience that this can be overcome by careful manufacture of the micanite. At the present time we have in the generators at Herring Run, dielectrics of this material that have been in constant use for six years without failure.

Glass dielectrics have been tried in an experimental way at this plant and are quite satisfactory, but our results tend to show that as these tubes have to be imported, on account of breakage they would probably be prohibitory.

The aspirators in use to-day are not the result of a chance design, but the logical result of several months of experiments, with various types of nozzles designed by Mr. Walden. They are of cast iron lined with porcelain, and so constructed as to furnish the maximum velocity of air with comparatively low head of water over the throats.

In the operation of ozonizers for water purification many factors must be taken into consideration, and it is due to a lack of comprehension of this fact that so many failures in this country at least have been experienced. The operator must keep a record of atmospheric conditions, as temperature and humidity have a considerable bearing not only on the purity of the gas, but the amount generated. Generally speaking, the concentration under uniform operating conditions is, up to a certain limit, in proportion to the electrical energy expended. This yield, as has been demonstrated, Fig. 9, could be increased by the use of oxygen, but such a procedure is without the sphere of practical application. Experience at the Herring Run plant has shown that high concentrations, at

least above a certain point, are not essential to efficient sterilization, as such concentrations cause a waste of ozone, as the gas passes through the mixing chambers unconsumed. We have experimented with concentrations ranging from .3 to 5.2 grams per cubic meter, and have found that under ordinary conditions a concentration of 1 to 2 grams is enough for efficient operation.

The amount of ozone required would vary in different places, as the organic matter present in the water is to a great extent an intimation as to the treatment required.

Since the operation of this plant has started many interesting and instructive lessons have been learned with reference to the effect of ozone upon the organic contents of water. Space does

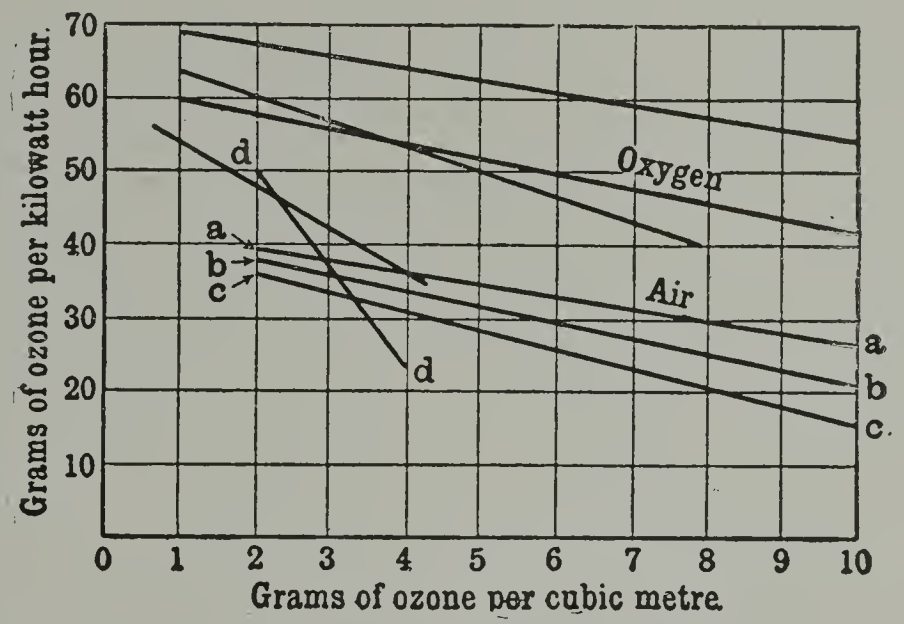


FIG. 9.—Yield of Ozone per Kilowatt Hour.

not permit us to go into the details concerning these experiments here, but it may be of interest to recite our experience with the action of ozone upon algæ.

It was noted that at certain times the ozonized water instead of being bleached was more highly colored. This, as was found out later, was due to the breaking up of certain types of algæ and similar organisms by direct oxidation of the ozone, and disseminating the chlorophyll matter through the water, the ozone having, as it was later proved, no bleaching effect upon this substance. These studies have also shown that the bacterial efficiency of the plant was reduced in proportion to the algæ content of the raw water supply, Fig. 10.

Waters containing excessive turbidity cannot be efficiently treated by this method, unless the turbidity is first removed by fil-

ters, owing to the fact that the bacteria may be to some extent mechanically protected from the oxidizing effect of the gas. We can, however, and have for long periods of time operated the ozone plant at Herring Run with a turbidity of about 40 parts per million, and by proper concentration and mixture have efficiently sterilized such waters. In one particular instance we operated upon a water, with a turbidity in excess of 100 parts per million and even under such conditions the bacterial efficiency was about 90 per cent reduction over the raw-water count. It is, however, customary to filter waters of this character before attempting ozonization, although

TABLE Nº 1

SHOWING THE EFFECT OF ALGAE GROWTH UPON THE EFFICIENCY OF OZONE STERILIZATION.

BACTERIA PER C.C.			ALGAE PER C.C.			CONCENTRATION
RAW	OZONIZED	% REMOVAL	RAW	OZONIZED	% REMOVAL	% O_3
1040	390	62.5	210	95	54.7	0.84
950	250	73.6	150	135	10.0	0.84
1500	210	86.0	90	30	66.6	0.92
400	40	90.0	NO ALGAE	NO ALGAE		0.84
2720	25	99.1	" "	" "		1.05
1400	14	99.0	" "	" "		0.84

FIG. 10.—Effect of Algæ Growth upon the Efficiency of Ozone Sterilization.

the failure of one plant at least was caused to some extent by disregard of this condition.

From the results that have been mentioned above it is readily seen that the use of ozone as a sterilization agent is considerably more efficient than many of the other sterilizing agents used for water purification at the present time, owing to the fact that it can be used efficiently with water containing turbidities and colors comparatively high, while the other sterilizing agents cannot be guaranteed to maintain their efficiencies under these conditions.

As is well understood, the principal object of ozone treatment

is sterilization, particularly the elimination of pathogenic organisms. To accomplish this, two conditions must be fulfilled. Ozone must be generated in quantities sufficiently great to oxidize these growths and the gas when so generated must be thoroughly and intimately mixed with the water under treatment.

Without attempting to dogmatize, it might be well to review briefly the use of ozone as a water purification agent and its application to this purpose.

If a water contains so excessive a turbidity, or a turbidity in such a state of fineness that it will require filtration at low rates with chemical coagulation, then such a water is not well suited to ozone sterilization, owing to the cost of double treatment.

There are on the other hand many types of surface waters in which the turbidity is never excessive or contains suspended matter in such a condition that plain sedimentation or filtration at very high rates will readily remove it. Such waters will lend themselves readily to ozone treatment. To this class might also be added highly colored waters, provided the coloring matter is such that it will be bleached by ozone.

There is no doubt but that the public generally leans toward a method of water sterilization which will efficiently sterilize the supply by means other than the use of chemical compounds. This, of course, is from an æsthetic standpoint; and from the after affects that have been experienced in chemically treated waters it is not surprising that the layman should take such a stand.

A more careful study on the part of the Engineering Profession of this method along these lines might indeed prove fruitful of gratifying results.

DISCUSSION

Dr. Olsen: I have done a good deal of work along the lines of this paper, and some of the results which I have obtained have been alluded to in Mr. Powell's paper. I have worked on the ozonation, not only of pure water, but of water containing large numbers of bacteria. In fact, in one series of experiments, I collected a considerable quantity of sewage and diluted it with Brooklyn water so as to have the bacterial content as high as 500,000 per cubic centimeter.

In these experiments I used a large type of ozonator supplied

by the General Electric Company. The tubes they used were of glass, upon which they deposited copper electrically, and there was a large rim on the upper end of each tube which held it in place in the ozonator. I do not think it was a perfect commercial success on account of the breakage of glass, which was very high.

I was much interested in the plant here, at Baltimore. In the machine which I used the air was dried by calcium chloride, but in this plant it is dried by refrigeration.

When I analyzed the ozonized water in the tests that I made I came to the conclusion that the ozone acts as a specific poison to the bacteria. Another observation was that spores were not destroyed, so that the water purified by ozone, if allowed to stand, will again generate or produce large numbers of bacteria.

It is also certainly interesting to confirm the information that Mr. Powell has stated that the turbidity does not interfere with the action of the ozone.

One more interesting fact, of which some of you may not be aware, is that Dr. Vosmaer, who has done a great deal of work on ozonation, has just written a very comprehensive book on this subject. It is published by D. Van Nostrand Company.

Mr. C. A. PATTERSON: I would like to ask Mr. Powell if it is possible for him to give us any cost data in regard to the power required in producing ozone and concentration, and volume of the ozonized water produced under average conditions of the Baltimore water used, so that we might get an idea of the cost of ozonizing and treating water in comparison with other methods.

Mr. POWELL: In reference to ozonation of sewage, we have never done any work along this line here in Baltimore, but we have treated surface waters highly polluted with sewage wastes. These results were very encouraging, considering the fact that the water previous to ozonation had received no treatment whatsoever before reaching the ozonators. Bacteriologically the samples were as high as 100,000 organisms per cubic centimeter, and these were reduced as much as 90 per cent, with the elimination of from 20 to 60 per cent of organic matter as measured by the required oxygen tests and 15 to 50 per cent of the total colors. Just what can be accomplished with ozone in the treatment of sewage I am not prepared at this time to say, but from the result of some 5 or 6 years' experience here on highly polluted waters we candidly believe that ozone can be made to give satisfactory results in the treatment of sewage;

provided it is used as a supplementary process for oxidation and sterilization of the final effluent.

What Dr. Olsen has said in reference to ozone acting as a specific poison upon bacteria, I have no knowledge of. I am of the opinion, however, that the ozone may oxidize certain organic compounds, and these oxidized substances may in turn act in the manner which Dr. Olsen has mentioned. This, however, is merely theoretical on my part, as I have no data to sustain this opinion.

It has been proven abroad that ozone has no effect on spores, but I think the question is not one which seriously affects or reduces the efficiency of sterilization of water by ozone in this country, as spore organisms are not pathogenic.

One reason for the violent after growths that often take place in sterilized waters, either from ozone or other sterilizing compounds, is due to the fact that when the water is first treated the organisms that are in a free state are readily removed by the sterilizing agent; after this, the suspended matter, provided the water has not previously been filtered, will break up, allowing the organisms within the particles of suspended matter to be scattered through the supply, and as there is no residual chemical to oxidize these organisms there is no check to their growth, and in this way they multiply very rapdily, causing the violent aftergrowths as have been mentioned above.

In answer to Mr. Patterson's question as to the cost of sterilization, I regret to say I am unable to give any specific figures. The reason for this is that many of the cost items entering into the operation of the Herring Run plant are development costs and have been so placed that they cannot be readily segregated from the whole, and in this way any costs as taken from the records could not be properly charged against the cost of the ozonizing plant under actual conditions. We can, however, give a rough estimate of what the cost of treatment of water at Herring Run is. This would be between 75 cents and $1.00 for the operation, with a total cost, including overhead charges, of less than $2.00 per million gallons of water treated, this to include filtration by roughing filters.

Dr. OLSEN: Mr. Powell mentioned aftergrowths due to suspended particles in the water. One particular water which I ozonized was remarkably clear spring water and any aftergrowths could not be possibly assigned to that reason, on account of the remarkable clearness of the water. After the ozonation treatment

the bacteria amounted to o, while the spores amounted to a very large number.

Mr. POWELL: Dr. Olsen has probably misunderstood me to some extent when I spoke of the aftergrowths that had been noted in sterilized water supplies. There is undoubtedly a certain amount of aftergrowths that take place from spores, as has been noted many times in treated water both in this country and abroad when the sterilizing agent did not kill the spores. There has been noted, however, a great deal of aftergrowths due to the breaking up of turbidity after ozonization, as was the case in the treatment of the water at Ann Arbor, Michigan, and the treatment of water by chlorin in the reservoirs of the Baltimore City supply. In both these instances this was due almost entirely to the breaking up of the turbidity, as has been noted above.

CHANGES IN THE VOLUME AND SPECIFIC GRAVITY OF LINSEED OIL FILMS ON DRYING

By G. W. THOMPSON

Read at the Baltimore Meeting, January 14, 1916

The purpose of this investigation was to determine whether any change took place in the volume and specific gravity of linseed oil and linseed oil paints during the drying, after having been applied in thin films in the usual way. It is a well-known fact that linseed oil, when spread in a thin film, changes from a liquid to a semi-solid substance and that during this change oxygen is absorbed from the air and carbonic acid, water and other decomposition products are given off.

A. H. Sabin[1] conducted an elaborate set of tests in which he showed the change in weight occurring during the drying of paints applied to 4 by 5 inch glass plates, and constructed curves which indicated that in many cases the increase in weight amounted to as much as 18 per cent, and that after the maximum increase in weight had occurred, there was a gradual decrease in weight so that in some cases the weight of the dried oil film finally was close to that of the oil when originally applied. This indicated first an absorption of oxygen with subsequent giving off of products of oxidation and decomposition.

J. C. Olsen and A. E. Ratner[2] conducted experiments to determine the increase in weight of linseed oil on drying, and also the amount of carbon dioxide and water given off. They found that at the end of seventy-four days the oil had increased in weight 18.05 per cent, that 5.21 per cent of carbon dioxide and 14.55 per cent of water had been given off. As the carbon in the carbon dioxide and the hydrogen in the water came from the linseed oil they concluded that the sum of the increase in weight of the oil and the carbon dioxide and the water given off would represent the actual amount of oxygen that had entered into combination with

[1] "German and American Varnish Making," Bottler and Sabin, p. 194 (Wiley).

[2] Transactions of Am. Inst. of Chem. Engs., Vol. V, p. 100, 1912.

the oil and its constituents. This sum amounted to 37.81 per cent.

It was evident to the writer that these chemical changes could not take place without corresponding physical changes, particularly in specific gravity and volume. He therefore arranged with one of his assistants, Mr. Arthur G. Belden, in the laboratory of the National Lead Company, to conduct an investigation similar to that of A. H. Sabin referred to, which was to apply to 4 by 5 inch glass plates coatings of linseed oil and various paints, observing the change in weight which took place on the exposure of these plates to the action of clean air. He went further, however, and determined the volume of the glass plates he used by weighing in water, and knowing the specific gravity of the oils and paints used, he was able to calculate their volumes from the amounts taken.

TABLE I

ORIGINAL COMPOSITION BY WEIGHT OF COATINGS APPLIED

Test No.	N.A. Raw L.O. %	S.A. Raw L.O. %	N.A. Boiled L.O. %	White Lead. %	Zinc Oxide. %	Red Lead. %	Whiting. %	Barytes. %
42								
43	100							
45								
46	.....	100						
47								
48	.....	.....	100					
49								
50	21.2	.....	.....	78.8				
51								
54	30.5	.....	.....	69.5				
55								
56	52	.....	.....	.....	48			
57								
58	26	.....	26	.....	48			
72								
73	21.7	.....	.....	.....	.....	78.3		
68								
69	35.7	.....	.....	.....	.....	.....	64.3	
70								
71	17.5	.....	17.5	.....	.....	.....	65	
59								
65	21.6	.....	.....	.....	.....	.....	.....	78.4
66								
67	10.4	.....	10.4	.....	.....	.....	.....	79.2

After the plates had been exposed for two hundred days and the weighings necessary for the oxidation curves made, the plates were again weighed in water, by which the final volumes of the films were determined. From these final film volumes the specific gravities of the oxidized films were calculated. It was assumed that no change in volume, weight or specific gravity of the pigments had taken place and that the changes took place entirely in the oil in the films. In this weighing no correction was made for the buoyancy of the air. Calculation indicated, however, that this buoyancy would have had no effect within the reported limits.

In Table I is given the original composition by weight of the coatings applied. In Table II is given the changes in volume and specific gravity finally observed. In the charts 1 and 2 are shown the oxidation curves. Table III, which shows the method of calculation followed in the case of one of the paints, is given as an example of the procedure.

TABLE II

FINAL SPECIFIC GRAVITIES AND CHANGES IN SPECIFIC GRAVITIES AND VOLUMES OF FILMS

Description of Film	PAINT FILM.			OIL IN FILM.		
	Final Sp.gr.	Per Cent Change of Sp.gr.	Per Cent Change of Vol.	Final Sp.gr.	Per Cent Change of Sp.gr.	Per Cent Change of Vol.
42. N.A. raw linseed oil....	.....	.....	.....	1.16	+24.2	−13.0
45. S.A. raw linseed oil.....	.....	.....	.....	1.15	+23.4	−12.4
47. N.A. boiled linseed oil..	.....	.....	.....	1.17	+23.9	−13.6
49. N.A. raw linseed 2 gals., white lead 100 lbs....	3.33	+15.6	−12.6	1.20	+28.5	−19.3
51. N.A. raw linseed 4 gals., white lead 100 lbs....	2.31	+17.3	−13.6	1.18	+26.3	−17.9
55. N.A. raw linseed zinc oxide.....	1.88	+22.1	−11.9	1.22	+30.6	−13.9
57. N.A. raw and boiled zinc oxide.....	1.89	+21.9	−13.1	1.23	+29.9	−18.0
72. N.A. raw linseed red lead	3.59	+16.6	−12.4	1.23	+31.7	−17.3
68. N.A. raw linseed whiting	1.85	+15.6	−11.6	1.22	+30.6	−18.9
70. N.A. raw and boiled whiting.....	1.85	+14.9	−10.6	1.22	+29.9	−17.7
59. N.A. raw linseed barytes	2.78	+15.8	−12.8	1.28	+37.0	−23.0
66. N.A. raw and boiled barytes.....	2.75	+12.2	−10.0	1.22	+29.9	−18.6

TABLE III

METHOD OF CALCULATION

		I Weight Gm.	II Per Cent Weight	III Sp.gr.	IV II ÷ III	IV Per Cent Volume
1.	Mixture, raw American linseed oil	24.5	21.21	.934	22.71	65.56
2.	" raw Argentine "					
3.	" boiled "					
4.	" white lead	91	78.79	6.6	11.93	34.44
5.	" zinc oxide					
6.	" bartyes					
7.	" whiting					
8.	" red lead					
9.	Sum	115.5	100.00		34.64	

			(Run A)	(Run B)
10.	Sp.gr. of mixture 100 ÷ 9 IV		2.88	2.88
11.	Original weight of plate in air		39.5698 gm.	50.2014 gm.
12.	" " " water at 25° C.		24.7680	31.2440
13.	" " " + film in air		40.3662	51.2962
14.	" " film in air	No. 13 − 11	.7964	1.0948
15.	Final weight of plate + film in air		40.3730	51.3055
16.	" " " + " water at 28° C.		25.3405	32.0305
17.	" " " + " " at 25° C.	Temp. corrections made	25.3303	32.0143
18.	" film in air	No. 15 − 11	.8032	1.1041
19.	" " water at 25° C	18 − (17 − 12)	.5623	.7703
20.	" oil in film in air	18 − 22 (constant)	.1757	.2415
21.	Original weight of oil in film	14 × per cent oil	.1689	.2322
22.	" " pigment in film	14 − 21	.6275	.8626
23.	" volume of oil in film	21 ÷ .934	.1808 c.c.	.2486 c.c.
24.	" " pigment in film	22 ÷ 6.6	.0950	.1307
25.	" " film	23 + 24	.2758	.3793
26.	Final volume of film	18 − (19 i.e. vol. of H_2O displaced)	.2409	.3338
27.	" " pigment in film	constant same as 24	.0950	.1307
28.	" " oil "	26 − 27	.1459	.2031
29.	" sp.gr of film at 25° C.	18 ÷ 26	3.33	3.31
30.	" " oil in film at 25° C.	20 ÷ 28	1.20	1.18

				(A) Gain	(A) %	(B) Gain	(B) %
31.	Gain in weight of film	$(18-14)=x$	$(x \div 14)=\%$	.0068 gm.	0.85	.0093 gm.	0.84
32.	" " oil in film	$(20-21)=x$	$(x \div 21)=\%$	.0068	4.02	.0093	4.05
33.	Decrease in volume of film	$(25-26)=y$	$(y \div 25)=\%$	.0349 c.c.	12.65	.0455 c.c.	12.00
34.	" " oil in film	$(28-23)=y$	$(y \div 23)=\%$	.0349	19.35	.0455	18.30
35.	Gain in sp.gr. of film	$(29-10)=z$	$(z \div 10)=\%$	.45	15.62	.43	14.93
36.	" " oil in film	$(30-.934)=w$	$(w \div .934)=\%$	.266	28.47	.246	26.34

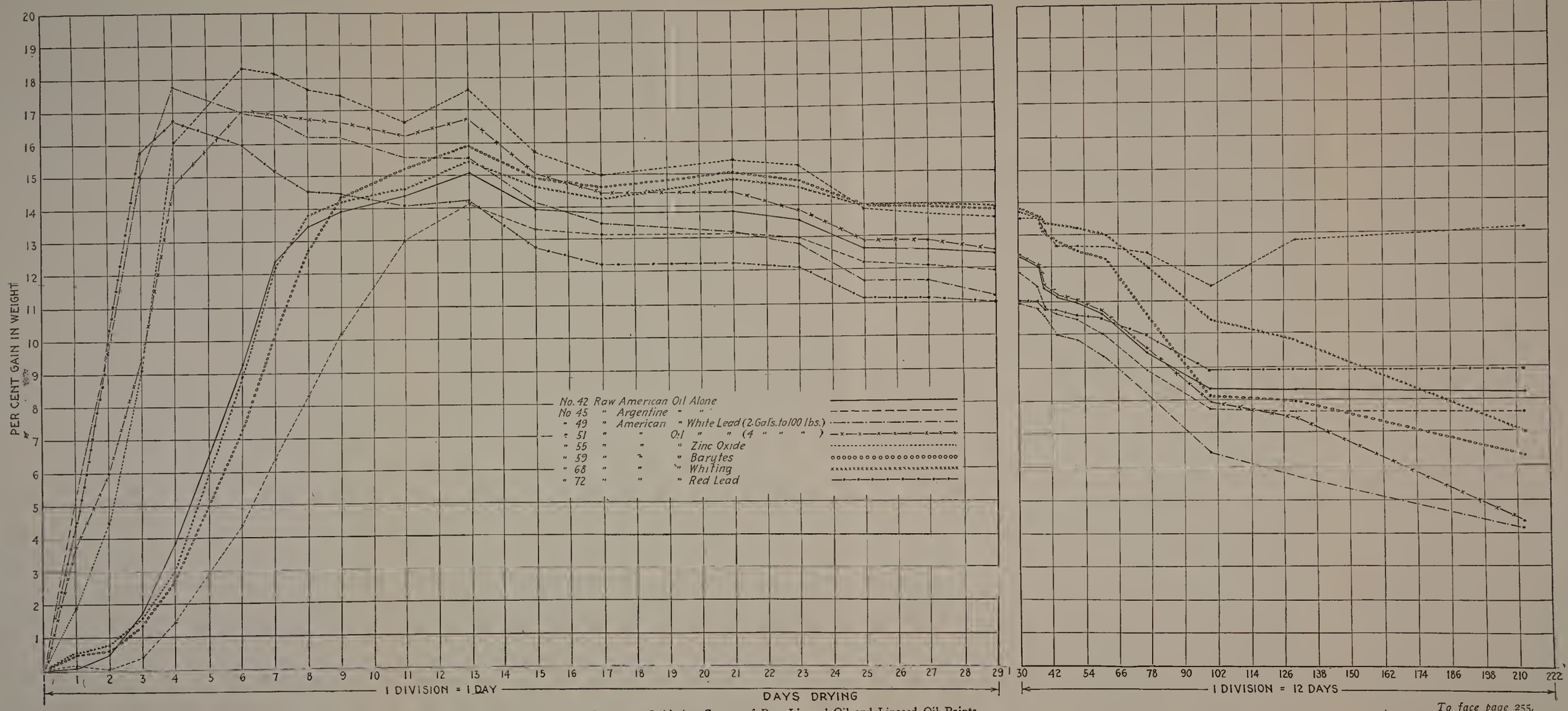

PER CENT GAIN IN WEIGHT
No. 42 Raw American Oil Alone
No 45 " Argentine " "
" 49 " American " White Lead (2 Gal's. to 100 lbs.)
" 51 " " 0:1 " " (4 " " ")
" 55 " " " Zinc Oxide
" 59 " " " Barytes
" 68 " " " Whiting
" 72 " " " Red Lead
1 DIVISION = 1 DAY
DAYS DRYING
1 DIVISION = 12 DAYS

CHART 1.—Oxidation Curves of Raw Linseed Oil and Linseed Oil Paints.

To face page 255.

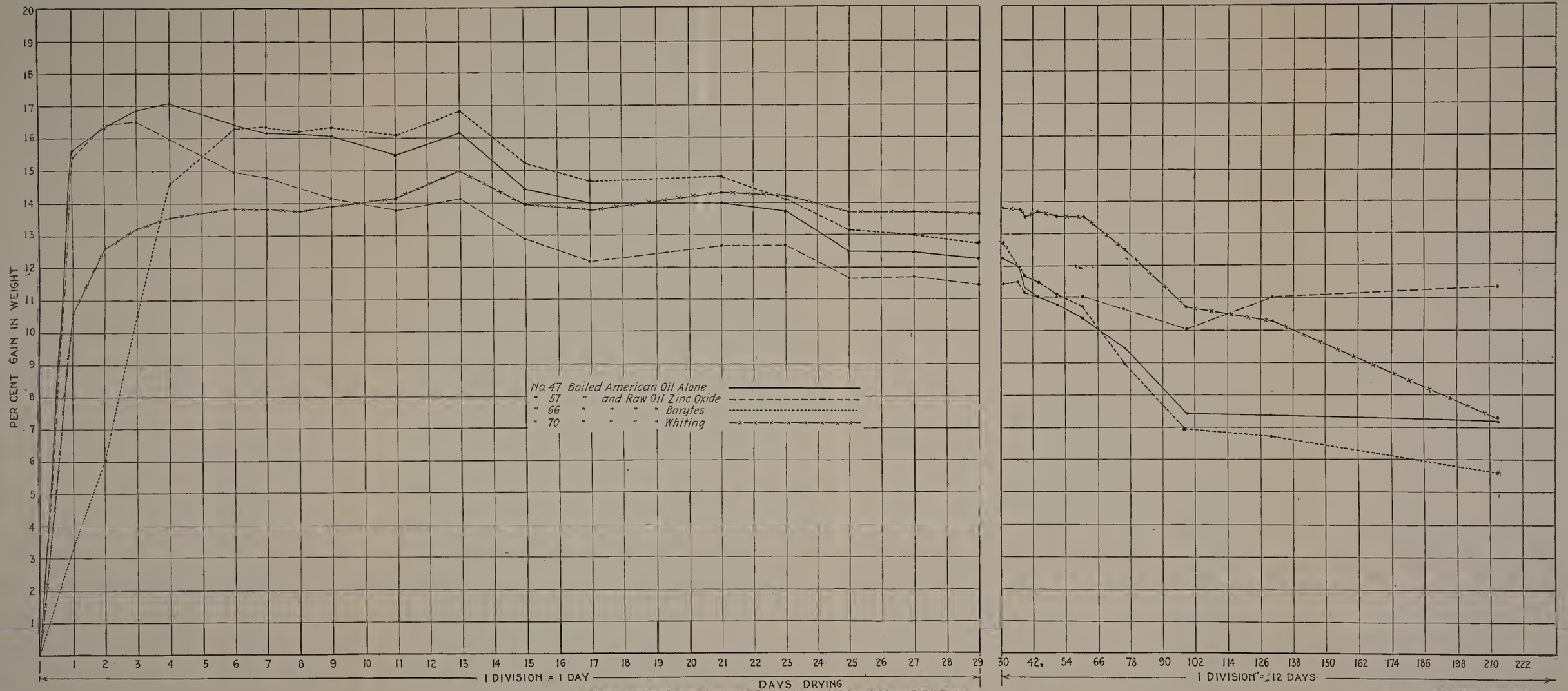

PER CENT GAIN IN WEIGHT
No. 47 Boiled American Oil Alone
" 57 " and Raw Oil Zinc Oxide
" 66 " " " " Barytes
" 70 " " " " Whiting
1 DIVISION = 1 DAY
DAYS DRYING
1 DIVISION = 12 DAYS

CHART 2.—Oxidation Curves of Boiled Linseed Oil and Linseed Oil Paints.

To face page 255.

The striking feature about these tests is that the specific gravities of the linseed oils used have increased from 23 to 37 per cent, and the volume has decreased from 12 to 23 per cent. The shrinkage in volume must have a bearing upon the durability of paints.

This work was undertaken for the definite purpose of finding out just what changes in specific gravity and volume occurred. It would be very desirable, of course, if a paint vehicle could be developed in which the changes in volume would be reduced to a minimum.

THE UTILIZATION OF WOOD WASTE

By ARTHUR D. LITTLE

Read at the Baltimore Meeting, January 12, 1916

Mark Twain says "We all talk about the weather, but nothing is done." So it is with wood waste utilization. The lumbermen are interested of course, but their interest is tempered by weariness and restrained by skepticism. They are open to conviction but would like to see anyone who can convince them. Much the same situation may be found where any of our great industrial wastes are concerned. Those who are responsible for the wastes are so close to them and so long familiar with them that they have come to regard them as the unavoidable accompaniment of the industry. Moreover plans for waste utilization commonly involve the extension of a business into regions which, however familiar they may be to those doing business in them, are new and strange to the makers of the waste. Conversely, those whose specialized experience might enable them to utilize the waste to advantage, hesitate to incur the large capital expenditure required for establishing an industry dependent upon a raw material over which they have no control and the supply of which may cease at any time, as, for example, when a lumber mill burns down.

These are real and serious obstacles in the way of the utilization of wastes, but the things which anyone can do easily bring no great rewards. The world belongs to those who overcome difficulties and nowhere does it offer richer promise of potential wealth made actual than in the colossal wastes of lumbering.

The figures involved are of astronomical proportions and consequently make little more impression on the mind than the distances of the fixed stars. Let us, however, try once more to really comprehend them. On a total annual cut of 50 billion feet, board measure, of merchantable lumber, at least 75 billion feet or about 112,000,000 tons of wood waste is produced. For every

man, woman and child in the country there is therefore annually wasted more than a ton of wood.

The proportion of waste to merchantable lumber varies within wide limits with the kind of wood. In the lumbering of hard woods, according to Goodman, only 15 per cent of the weight of the standing timber appears as finished lumber. Sixty-five to seventy per cent of the original tree is left on the ground and the mill waste amounts to over a cord per 1000 feet of lumber. Frankforter, who had exceptional opportunities for studying the lumber industry in the middle, northern and western states, reports that in these sections of the country the best equipped and most skillfully operated mills utilize a little less than 40 per cent of the total weight of wood in lumber, lath and shingles. Our own large scale studies on long leaf yellow pine have proved that under the best operating conditions only 33.42 per cent of the average tree becomes available as lumber, box shooks, lath and shingles. Two-thirds is wasted. In the estimate given above of total annual waste an average of 60 per cent of the entire tree was reckoned as waste, but in view of the loss on yellow pine, which is our most important timber tree and the far greater proportionate loss on hardwoods, it is evident that the total annual waste is substantially more than 75 billion feet and may even reach 90 billion feet. Frankforter's estimate of 100 billion feet on a smaller annual cut is undoubtedly too high and not in accordance with his other figures.

Of all our timber trees none lends itself more readily to waste utilization than long leaf yellow pine. It is cut more largely than any other species and the individual operations are commonly on a great scale which ensures the local concentration of waste in vast amounts. For these reasons and because my associates and I have studied the waste utilization problems presented by this wood more carefully than those of any other species I will ignore hardwood distillation, the use of extracted chestnut chips for pulp and paper making and the occasional use of mill waste from northern conifers in sulphite pulp mills, and ask you to direct your attention solely to the utilization of wood waste from long leaf yellow pine.

The present annual cut of this species is about 15 billion feet, board measure. The waste is equivalent to 30 billion feet. It may be said at once without fear of successful contradiction that the potential profits in this waste are far greater than any actual

profits which this branch of the lumber industry can be made to yield from lumber. When this waste is intelligently considered, not as waste but as raw material, it will be seen to afford a basis for building up the greatest group of correlated by-product industries the world has ever seen. The products of these industries will comprise wood pulp, pulp boards, paper, paper bags, paper twine, turpentine, rosin, pine oil, charcoal, tar, ethyl alcohol, cattle feed, varnishes, ether, and not improbably acetic acid, wood alcohol, acetone and producer gas.

The wood of long leaf pine is heavy, exceedingly hard, very strong, tough, coarse-grained, compact, durable and very resinous. Its density varies with the height from the ground, the age of the tree and its content of pitch or oleoresin. Sargent gives the average sp. gr. as about 0.7, which would seem to be too high. Determinations in the Forest Products Laboratory ranged from 0.426 to 0.583. Determinations in our own laboratory gave 0.626 as the sp. gr. of round wood averaging 7 inches in diameter. The weight per cubic foot for logging waste we found to be 39.1 pounds bone dry. The weight per cord depends greatly upon the shape and size of the pieces. On the dry basis we have found the sawdust to weigh about 1400 pounds, mill waste with little or no bark 2340 pounds, with much bark 1708 pounds, logging waste in the form of fairly smooth round logs weighs about 3260 pounds and if rough and irregular will average 1860 pounds, while mature long leaf pine consisting largely of heart wood will run about 4300 pounds to the cord, bone dry.

We find the ultimate composition of long leaf pine to be:

	Per cent
Carbon	53.96
Hydrogen	7.13
Oxygen	38.65
Nitrogen	0.03
Sulphur	0.04
Ash	0.16
	100.00

Our determinations of fuel value of average sawmill dust gave 9240 B.T.U., dry basis. Moisture in green wood averages 34.15

per cent, fresh green stumps average 28.69 per cent, lightwood 13.35 per cent. Stumps about six years old carry around 20 per cent of water and kiln dried lumber contains an average of about 10 per cent.

The proportion of bark varies to some extent with the age of the tree and is relatively high. Small round Mississippi wood had about 9 per cent, Florida pulp wood over 11 per cent and Florida trees 18 inches diameter, bore 8.6 per cent of bark by weight.

Determinations in our laboratory of the fiber length of long leaf pine gave a maximum of 7.40 mm., minimum 3.00 mm. with an average of 4.60 mm. as compared with 3 to 3.5 mm. for spruce.

In determining the amount of field waste under careful operation, members of our organization selected five plots of one acre each as truly representative as possible of the average quality of yellow pine timber. As soon as the timber had been felled the waste between 3 inches and 9 inches was collected, classified and weighed. Much of it was also corded and scaled to determine relations between weight, cord measure and volume. Each stump was measured and its volume and weight computed. Needles from four trees were weighed.

The main points of accumulation of mill waste are the main refuse conveyor and the main dust conveyor. Actual determinations by weight of the amounts of waste carried by these conveyors in very large scale operations were made by members of our staff. The results of these determinations in the field and at the mill enable us to state with a very close approximation to the truth the relative proportions of the initial products of the average yellow pine tree. They have perhaps never been ascertained before within such limits of accuracy or upon so large a scale. The proportions of the several products are as follows:

	Per cent
Tops and culls	22.35
Logs	70.56
Stumps and lightwood	7.09
	100.00

Bearing in mind that all percentages given are on the total weight of the tree, the tops and culls consist of

	Per cent
Needles and twigs	2.25
Limbs under 3 inches	2.54
Cordwood	6.42
Pulpwood	4.54
Red and rotten	6.60

The logs yield:

Red and rotten	1.45
Slabs, edgings and trimmings	18.07
Sawdust and shavings	17.62
Shingles	0.06
Lath	1.39
Lumber and box shocks	31.97
Stumps amount to	6.48
and lightwood to	0.61
	100.00

Comprehensive studies were conducted on these wastes for a period of eight months. The different classes of waste were carefully and repeatedly analyzed and their content of rosin and turpentine determined. Papers in great variety were made in our experimental paper mill under the direction of Mr. V. E Nunez, and extractions and distillations on the small commercial scale carried out in our Forest Products Department by Dr. L. F. Hawley. The results obtained, together with data from actual commercial practice point incontestably to these stupendous totals:

Upon an annual cut of 15 billion feet of yellow pine, the lumber industry in our southern states now wastes raw material sufficient for the concurrent daily production of 40,000 tons of paper, 3000 tons of rosin, 300,000 gallons of turpentine and 600,000 gallons of ethyl alcohol together with fuel sufficient to meet the requirements of all these industries.

Despite the prevailing opinion to the contrary among lumbermen and even among papermakers, long leaf yellow pine lends itself admirably to the manufacture of paper. It is too pitchy for the sulphite process but is readily reduced to pulp by the soda process.

Much the best results are, however, obtained by the sulphate process which, when carried out under proper conditions, yields an excellent kraft pulp and paper. The pulp bleaches with some difficulty but may with care be brought to good color without serious impairment of strength. The bleached pulp makes good wood writings and when mixed with pulp from gumwood can be run off into good book papers. A cord and one-half of round waste makes a ton of paper as against about 2 cords of spruce costing northern mills from $9 to $13 a cord.

The production of ethyl alcohol from yellow pine waste by the Ewen & Tomlinson process has been fully demonstrated as a technical proposition, about 90,000 gallons of high grade 95 per cent alcohol having been made in the plant of the Standard Alcohol Company at Fullerton, La. The commercial merit of the proposition remains to be demonstrated since this company is now in the hands of the receiver for reasons altogether apart from the technical merit of the process. It may, however, be said that every technical man familiar with the process believes that it is capable of producing 95 per cent alcohol at a cost, including cooperage and all fixed and manufacturing charges, of not more than 20 cents a gallon. Such alcohol is worth to-day about 56 cents a gallon. The yield per cord of sawdust or hogged wood waste containing 50 per cent water is 10 gallons in large scale operation, but yields much higher have been obtained in the laboratory.

The process is based, of course, on the observation of Braconnot in 1819, that cellulose by treatment with mineral acid is converted into reducing and fermentable sugars. For nearly one hundred years experimenters have endeavored to develop this observation into a commercial process. With the exception of Ewen & Tomlinson all have failed to produce alcohol in commercial quantities. Simonsen, in Sweden, in 1889 began a series of brilliant researches which cleared up many points of difficulty and ultimately enabled him to secure very satisfactory results on the large laboratory scale. Attempts at commercial operation, however, developed fresh obstacles and led to the abandonment of the process. The well known German chemist, Alexander Classen, patented during the years 1900, 1902 and 1903 various modifications of the general process of producing sugars and alcohol by treatment of comminuted wood with strong acids under heat. Subsequently several plants were built in this country for carrying out one or another of

these modifications. In none of them were any substantial amounts of alcohol produced and the Classen process must be regarded as commercially inoperative. It remained for Ewen & Tomlinson to overcome the fundamental technical difficulties underlying all these attempts and to put forward the first process capable of large scale production of ethyl alcohol from wood.

The Ewen & Tomlinson process is essentially one for producing fermentable sugars. The fermentation of these sugars, once produced, may be carried out and the alcohol recovered in any distillery by the usual methods. It is my belief that the process affords the cheapest known method for producing these sugars and that it therefore is ultimately destined to become an important if not the most important source of industrial alcohol.

In carrying out the process hogged wood waste usually containing about 50 per cent of water is loaded into a rotary digester holding about 7 cords and having a protective and heat insulating lining. Sulphuric acid in relatively small amount is sprayed upon the wood and then steam is admitted to the digester. The critical temperature is reached as quickly as possible and the reaction is then extremely rapid if not indeed nearly instantaneous. Pains are therefore taken immediately to reduce the pressure and to empty the digester of its contents as promptly as may be. About 25 per cent of the weight of the wood is converted to reducing sugars, not all of which are fermentable.

The cooked material which is not unlike coarse coffee grounds in appearance is transferred by conveyors to a diffusion battery or other extraction apparatus in which the sugars are dissolved out. The spent chips go to a continuous press for removal of excess water and are then available as fuel. The extracted juice is neutralized with lime and is then ready for fermentation. The concentrated slop from the stills finds use as cattle feed and is about equivalent to molasses for that purpose.

In a modification patented by me the process may be diverted as a whole to the production of carbohydrate cattle feed. In this modification hydrochloric acid is substituted for sulphuric and subsequently removed so far as readily possible by heating or blowing air through the mass. The remaining acid is then converted to common salt by addition of an equivalent amount of sodium carbonate. The juice is extracted and concentrated to the consistency of molasses.

A major economic problem in the South which is bound up with the utilization of wood waste is that of the agricultural development of the cut over lands. It has been demonstrated that by a steam puller yellow pine stumps may be pulled for about 33 cents each. In the trials made the stumps averaged 563 pounds each, which makes the cost of pulling $1.16 per ton. Where logging tram roads are still in place the stumps can be brought to a central plant for treatment at a total cost well within $2.50 per cord. Treated by solvent extraction they should yield per cord about 6 gallons of turpentine, 2½ gallons of pine oil and about 380 pounds of rosin. The extracted chips as pointed out by Veitch and Merrill and amply demonstrated in our experimental paper mill are available for the manufacture of an excellent grade of kraft paper. Strangely enough and contrary to our first impression the charred portions common in such stumps are easily removed in the process and leave the paper clean. The chips are, of course, also available for alcohol production.

Stumps and the highly resinous wood residue termed lightwood, together with the box slabs from turpentined trees, are directly available for treatment by several processes of distillation. The average green wood with 35 per cent moisture contains about 6 per cent rosin, but in selected samples of wood the rosin may run higher than 50 per cent. No large quantities are usually to be had, however, containing more than 30 per cent. The composition of the rosin itself is variable, but in green wood it runs about 80 per cent rosin, and 20 per cent volatile oils; about 80 per cent of the latter are turpentine and the balance pine oil.

Destructive distillation is carried on in retorts operated commonly without temperature control. Average yields under these conditions are:

Light oils	6	gallons
Turpentine	6	"
Heavy oil	16	"
Tar	48	"
Charcoal	35	bushels

Various processes in which the retort temperature is controlled as in the bath process and the processes of Cautier, Pritchard and others, have been proposed and several put in operation for a time

on either the commercial or large experimental scale. They offer advantages in the way of better yields and quality of turpentine but these gains are so nearly offset by higher fuel costs and higher maintenance charges that the commercial superiority of these more complicated processes has yet to be demonstrated.

Ten years ago recovery of turpentine from comminuted waste by steam distillation was practiced in many plants, the steam being blown through the mass of chips either upward or downward and carrying with it to the condenser the volatile oils. The decline in the price of turpentine in 1907 and 1908 proved so severe a blow to the industry that it is to-day practically wiped out.

The well known Yaryan process added to the steam distillation method the subsequent step of extracting the chips with a volatile solvent from which the dissolved rosin could later be recovered. Several plants of large capacity were operated successfully until in 1913 the failure of the American Naval Stores Co. caused a heavy drop in the price of rosin which was followed by the failure of the company operating the Yaryan process. A contributory cause may well have been the large losses of solvent incident to the process.

Several methods have been proposed for the recovery of turpentine, pine oil and rosin from yellow pine wastes by the action of water solutions of alkali, but none are thought to be operating commercially. They depend upon the fact that the wood is only slightly attacked by the dilute alkali in which the rosin is readily soluble. Nevertheless some wood is dissolved and the difficulty of separating this so-called "humus" from the rosin has prevented the introduction of processes of this type. The difficulty has been overcome in a simple and ingenious way by Whitaker and Bates, who salt out the rosin soap by increasing, after the initial treatment of wood, the concentration of the alkaline solution to 3½ per cent free alkali. The treated chips are then available as a raw material for paper making.

When the real work of wood waste utilization has once begun and the attention of chemical engineers and financial men has been drawn more generally to the huge potential values now ignorantly thrown away, we may expect the rapid development of these by-product industries and the initiation of many new ones to the great enrichment of the South and in somewhat less degree, that of the Northwest. It would doubtless be too sanguine to expect the direc-

tive impulse for this new development to come from the lumbermen themselves. They are too close to the wastes. They are blinded by the sawdust. But if they fail much longer to grasp the opportunity which has been so long beside them they must be content to see others reap the benefits and profits which will come through control of processes, special apparatus and above all, of technique.

THE PRODUCTION OF AMMONIA FROM CYANAMID

W. S. LANDIS

Read at the Baltimore Meeting, January 12, 1916

INTRODUCTION: After working for many years on the problem of the fixation of atmosphere nitrogen in the form of cyanides and cyanamides, the outbreak of the Boer War forced Professors Frank and Caro of Berlin to turn their attention to the utilization of their products otherwise than in the field of precious metal extraction. A consequence of the then existing economic situation was the discovery of the process of transforming the cyanamide compounds into ammonia. United States Patent No. 776,314, granted November 29, 1904, most probably represents the first American publication on the subject.

According to the specifications of this patent various cyanamide compounds and derivatives, including the crude form of the calcium salt sold under the name of Lime Nitrogen, when treated with steam or water in the proportion of three molecules of water to two atoms of the nitrogen in the cyanamide salt, will yield ammonia. It is recommended in the specifications that the reaction be carried out at temperatures from 160°-180° C. in a closed vessel, though the claims of this patent cover temperatures above 100° C.

There has grown around this process and its later refinements in the last fifteen years an extremely important ammonia industry. Naturally the greatest development has been in Europe, its home, and it is only within the past year that a plant comprising full size apparatus has been in operation in the United States. In attempting to catalogue the various plants throughout the world which have been converting Cyanamid into ammonia in large scale operations, I find that available information, particularly since the outbreak of the European War, is so incomplete that the listing in consequence was very inaccurate. It is certain, however, that the transformation of cyanamid into ammonia is successfully carried out in Norway, Germany, France, Switzerland, Italy and Japan, and prior to the war in Belgium, the bulk of the product going into

ammonium sulphate for the chemical and fertilizer trade. Norway is producing large quantities of ammonia used in the Birkeland-Eyde plants for the production of ammonium nitrate; France has produced considerable quantities of anhydrous ammonia by this process; at the present time Germany is producing enormous quantities of nitric acid from this cynamid-ammonia by a newly developed oxidation process, and is erecting cyanamid plants equipped with ammonia apparatus at various places.

The fixation of atmospheric nitrogen, chiefly due to our Government's policy in respect to water power development, has not been practiced in the United States. During the year 1914 contracts were let in Germany by the American Cyanamid Company for the equipment of the largest single ammonia plant then projected or operating in the cyanamid industry, but the outbreak of the European war interfered with the shipment of this apparatus, nearly all of which was seized by the German Government for the purpose of providing for its own explosive requirements. It was possible to bring only a small portion of this equipment over to the States where it was set up and put into operation, and is now producing several tons of pure ammonia gas per day. This plant has been in continuous operation here for six months without any signs of trouble whatever and is considered to be most successful and satisfactory in every way.

RAW MATERIALS: The crude Cyanamid or Lime-Nitrogen is now a well-known commercial product. The Canadian factory supplying the United States and its insular possessions with this product has a capacity of fixing nitrogen equivalent to 90,000 pounds of ammonia per day, and with the completion of certain additions now being made will be capable of supplying some 110,000 pounds of ammonia each 24 hours. The demands for this product, most of which goes into the fertilizer industry, are so great that the plant is now operating at its full rated capacity. It is therefore evident that the supply of raw material for an ammonia industry is in no sense limited.

Crude Cyanamid, or Lime Nitrogen, the reagent used for the production of ammonia, is an electric furnace product, whose production has been described elsewhere by the writer.[1]

This material as turned out of the furnace contains nearly 25

[1] *Journal of Industrial and Engineering Chemistry*, **7**, No. 5, page 433, May, 1915.

per cent nitrogen in the form of $CaCN_2$, 12 per cent CaO and 12 per cent carbon, with miscellaneous impurities derived from the various raw materials entering into its manufacture.

The other raw materials entering into the ammonia process are soda ash and hydrated lime. The quantities used are small, being approximately 3½ per cent and 2 per cent respectively of the weight of Lime Nitrogen used. Steam and power requirements which vary with the size of the plant are discussed later.

CHEMISTRY: On treating Lime Nitrogen with steam ammonia is produced from the calcium cyanamide according to the following reaction:

$$CaCN_2+3H_2O=CaCO_3+2NH_3$$

The reaction is almost quantitative when carried out on a large scale according to the process to be described later in detail. This reaction is exothermic in character, and while the exact heat of formation of calcium cyanamide has never been determined accurately it is believed that the heat evolution from the decomposition of the cyanamide alone amounts to between 200 and 300 pounds cals. per pound of ammonia evolved. This plays an important part in the present method of carrying out the process, inasmuch as after once starting the reaction under proper conditions it will proceed of itself, and, in fact, with such great velocity that only complicated and highly developed apparatus can take care of the gaseous products.

The process as carried out in the plant operating in the United States is essentially that described in the specifications of United States Patent No. 1,149,633, dated August 10th, 1915, "Process of Making Ammonia from Calcium Cyanamid."

In order to take advantage of the exothermic character of the reaction, as above stated, the process is made to take place in an autoclave partly under high pressure. This apparatus consists of a steel tank approximately 6 feet in diameter, 21 feet high and capable of operating under a working pressure of 300 pounds per square inch. It is provided with a powerful stirring apparatus. Into this autoclave is charged about 12,000 pounds of mother liquor derived from a previous operation (fresh water to start), and Lime Nitrogen is slowly fed into this liquor under continuous agitation. As the Lime Nitrogen contains always a fraction of a per cent of undecomposed carbid, acetylene is evolved during this dissolving of

the Lime Nitrogen. A proper ventilating system is provided to remove this acetylene at such dilutions as will be non-explosive even if subjected to a source of ignition. The charging is usually carried on over a period of an hour so as to insure thorough incorporation of the Lime Nitrogen with the solution and the breaking up of all lumps in the slurry. When the Lime Nitrogen has all been added to the autoclave the reagents—soda and lime—are added for the purpose of increasing the efficiency of ammonia evolution, principally through prevention of the formation of polymeric forms of cyanamide compounds which are difficult of transformation into ammonia. The autoclave is then closed up and steam is admitted for approximately 15 minutes, or until the pressure gauge on the autoclave indicates 3 or 4 atmospheres, which shows that the temperature in the autoclave has been raised sufficiently to start the reaction at a fair rate of speed. The reaction then proceeds of itself, generating ammonia and steam in the autoclave, and it is necessary to relieve this gas accumulation by means of suitable valves to avoid excessive pressures in the apparatus. The rate of reaction becomes cumulative as the temperature rises, and this relief of ammonia and steam must be permitted. Under normal working conditions the pressure in the autoclave will rise to about 12-15 atmospheres in the course of about 20 minutes with the relief valve open. The pressure then drops off slowly, as the gas is discharged, the rate of discharge being usually regulated by the attendant at the valve so as to maintain a constant pressure in the ammonia line, and at the end of about one and one-half hours from the start of the operation the evolution has usually stopped. Nearly all of the cyanamide in the charge has been decomposed during this first period of the operation, but the solution is still highly charged with ammonia, which it is necessary to expel. A very small amount of undecomposed Lime Nitrogen may be left, particularly of polymerized forms, which yield up ammonia only slowly. The steaming operation is then repeated, this time introducing steam until the pressure of the autoclave goes up to 6-8 atmospheres. The ammonia discharge valves are again opened until the autoclave is discharged, requiring a period averaging approximately one-half hour for this second discharge. In order to insure practically complete evolution of all the ammonia in the autoclave it is advisable to again repeat the steaming to 6-8 atmospheres for a third period, discharging as before. During this last period of steaming and dis-

charge rarely over 2 per cent of the total ammonia as charged is evolved, and it can, therefore, be omitted if extraordinary demands on the capacity of the apparatus are made.

Extended studies of the course of this decomposition of Lime Nitrogen in the autoclave have been made both abroad and in this country, and are here reproduced in the form of charts. The discharge from the autoclave consists of a mixture of steam and ammonia, the composition progressively changing during the cycle.

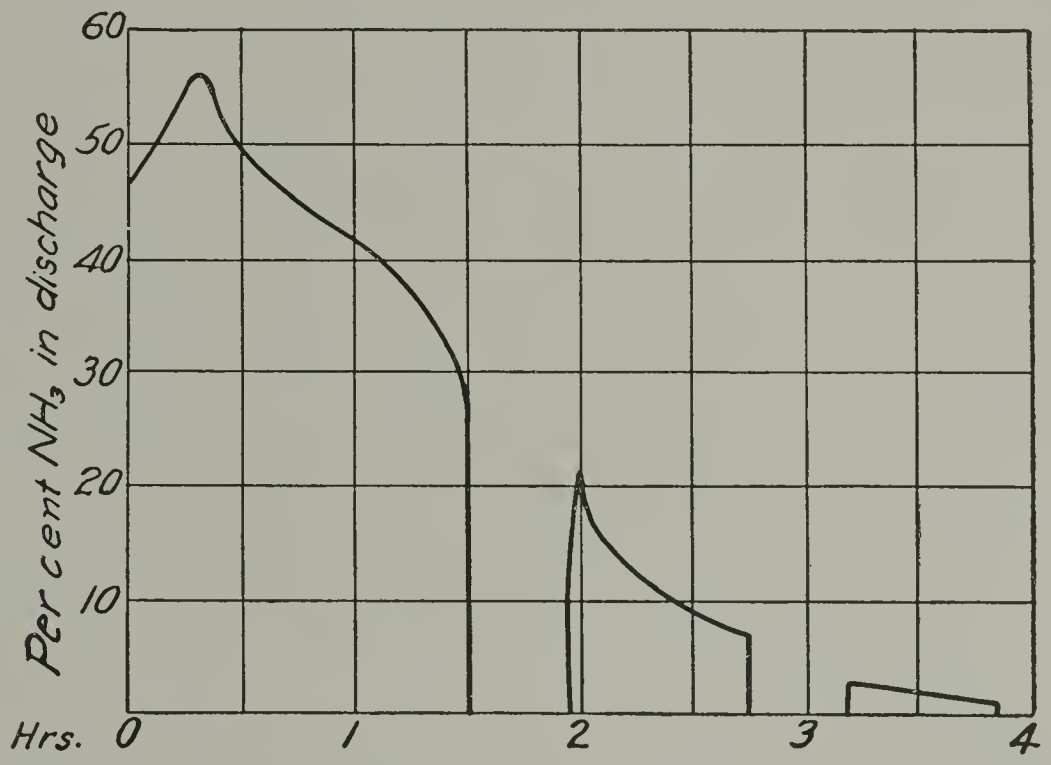


Fig. 1.—Percentage of Ammonia in the Ammonia-Steam Discharge of Autoclave.

This variation in composition is shown for an actual operation carried out in this country in Fig. 1, in which the ordinates represent the percentage of NH_3 by weight in the ammonia-steam mixture discharged from the autoclaves, and the abscissa the time after start of the operation, analyses of discharge being made at approximately three minute intervals.

The rate at which ammonia is discharged from the autoclave under operating conditions varies with the imposed condition. It has been found that most requirements are met by discharging at such rate as to maintain a constant pressure of steam and ammonia in the main leading from the autoclave. Under such conditions the rates of discharge during a given operating cycle are represented by the curve in Fig. 2, in which the ordinates are the pounds

of ammonia discharged per hour, and the abscissa again the various elapsed times from the start. In this case the charge in the autoclave was 7000 pounds of Lime Nitrogen analyzing about 26 per cent equivalent NH_3.

Where a uniform supply of ammonia is required it can be obtained by the insertion of a special type of gasometer in the system. Also suitable grouping of a number of autoclaves and cyclical operation of the same will assist greatly in obtaining a uniform rate of production without the use of such gasometer.

In Fig. 3 is shown a curve of the pressures existing in an

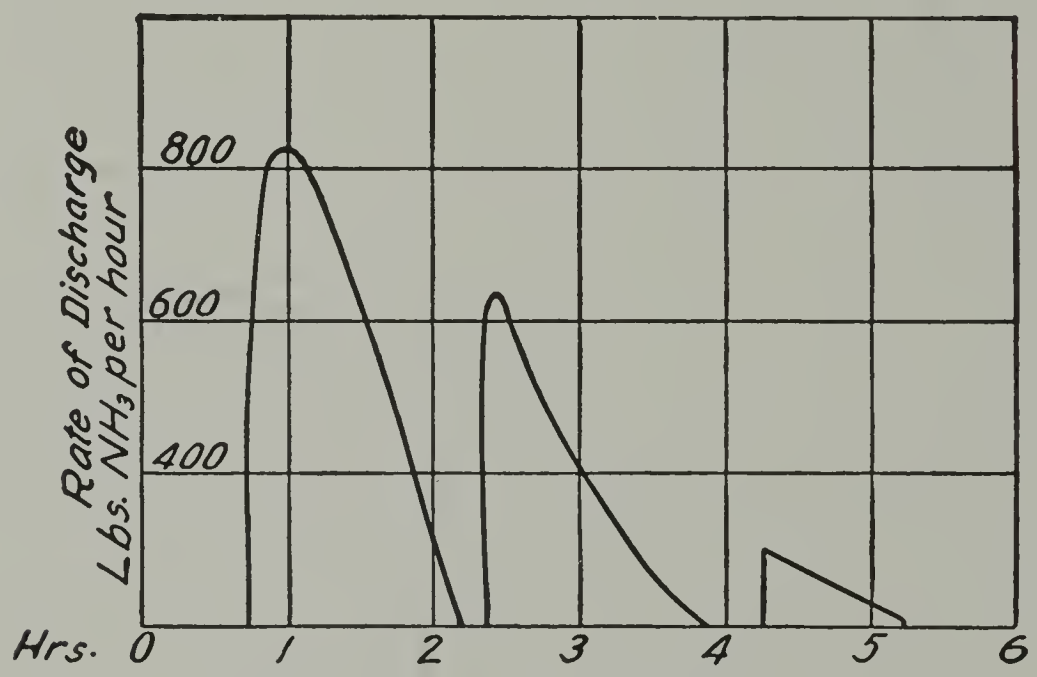


Fig. 2.—Pounds of Ammonia Discharged per Hour.

European autoclave, slightly smaller than the one described above, and operating on a charge of 8000 pounds of Lime Nitrogen. The dotted lines represent the admission of steam, and the full lines the pressures as shown on the gauge on the autoclave. The ammonia discharge valves of the autoclaves are opened where the lines are indicated double.

At the close of the operation the bottom discharge valve is opened and the mud contained therein runs by gravity into large suction filters of the well-known "Nutsche" type. Here the liquor is sucked off from the solid constituents, a thorough wash with water is given and the sludge removed to the dump. Under normal operating conditions this sludge when dried contains less than 0.2 per cent of equivalent ammonia, and about 65 per cent of CaO in the forms of carbonate and hydrate. It is dark gray or black in color,

due to the carbon present, and finds application as an agricultural lime. The liquor removed from the filter is used in dissolving the next batch.

HANDLING THE GAS: In the manufacture of ammonium sulphate, as carried out extensively abroad, the mixture of steam and ammonia coming from the autoclave is led directly into an absorber and produces a high grade white sulphate. This production of sulphate is much simpler than from ammonia liquor. Where the introduction of the accompanying steam is not permissible, as in the production of certain ammonia salts which cannot be subjected to

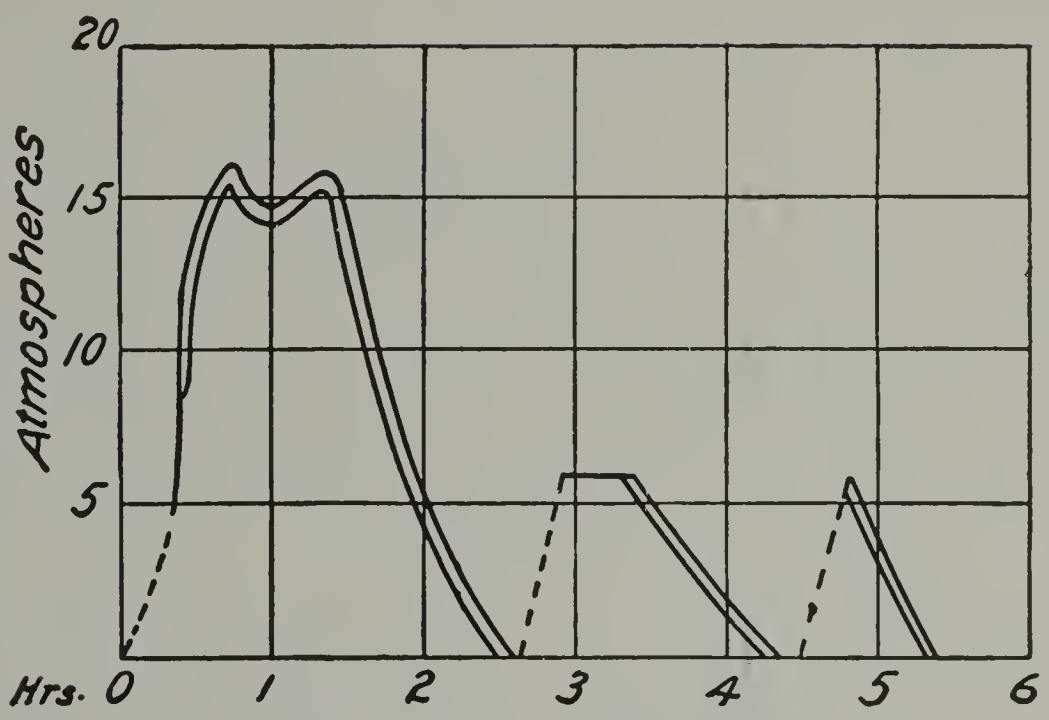


Fig. 3.—Pressure in Autoclave.

high temperatures, or where the process involves subsequent evaporation and crystallization, the ammonia-steam mixture coming from the autoclave is passed through a simple rectifying column provided with dephlegmator and condenser, and there is obtained therefrom a practically chemically pure ammonia gas, saturated with moisture at the temperature of the condensing water. This rectifying column is self-acting because of the large quantity of steam admitted with the ammonia-steam mixture, and requires no attention whatever in its operation, other than to shut off the cooling water to the condenser when not in use.

The ammonia derived from the column, as before mentioned, is practically chemically pure, and is used directly in a large number of chemical industries. The Birkeland-Eyde engineers absorb this ammonia gas in distilled water, forming a dilute aqua ammonia,

which they add directly to their dilute nitric acid for the manufacture of ammonium nitrate, the product being of extraordinary quality. On the other hand, ammonium nitrate of equal grade may be produced directly from the ammonia gases dehydrated in the column without the water absorption step.

One of the large autoclave plants in France has been manufacturing anhydrous ammonia for years, and in addition to the above purification system they have installed an oil washer, charcoal filter and lime drying boxes before liquefaction. The oil washer, the writer was informed, was installed to remove some very minute traces of an unknown organic compound, but he has inferred that the character and quantity of this impurity, from the manipulation of this apparatus, is largely mythical.

For the production of nitric acid from ammonia, the product as taken from the condensers attached to the ammonia column is so pure that no trouble is occasioned by the poisoning of the catalyzers used in its subsequent oxidation.

COMPLETE PLANT: I have with me assembled drawings of an autoclave plant of 16 autoclaves, such as supplied the Birkeland-Eyde Co. which is similar to those intended for this country. The rated capacity of the plant is 75,000 pounds of ammonia gas per day. The general arrangement of the apparatus, piping, etc., is clearly shown here by the use of colored inks, and I am sorry that photographic reproduction does not bring out the details of these drawings so that they can be shown in a more convenient form. Owing to the present inability to obtain this apparatus from Germany where it has been manufactured on an extensive scale, the American Cyanamid Company has redesigned the whole equipment, adapting it to American standards and manufacturing conditions, and is now building this equipment in the United States.

EFFICIENCY OF DECOMPOSITION: An extended study made by the writer a year ago of one of the European plants which had been in operation for a long time, showed that the transformation efficiency of the nitrogen in the Lime Nitrogen into ammonia was over 99 per cent. Our American plant is showing operating efficiencies covering a period of several months substantially equal to the above.

AUTOCLAVE PLANT: An economical autoclave unit is one of eight working shells. As the operating load factor on these autoclaves is very close to 100 per cent it is not necessary to supply

more than one spare shell to this eight autoclave equipment to insure a full 100 per cent load factor. Such a plant of eight autoclaves would require a 300 horsepower boiler. It was the old practice abroad to set the safety valve on the autoclave shells at 20 atmospheres and operate the boiler at this same pressure. In our own designs here in the States we have successfully operated at 125 pounds steam pressure without trouble and can take steam from a common plant main. Superheated steam is preferable for the purpose, but not absolutely necessary. There is in addition required for operating the Lime Nitrogen feeding device, the stirrers in the autoclaves, the vacuum pump and the air compressor, and miscellaneous sludge disposal equipment a continuous motor load of approximately 100 horsepower (the connected motor load would probably average about 200 horsepower, depending upon local conditions).

Operating Costs: In the compilation of a cost sheet for the production of ammonia from Lime Nitrogen there is such great latitude in unit costs concerned that the writer is presenting rather full quantitative data to which he is appending assumed unit costs. In most cases the assumed unit costs are averages existing before the outbreak of the European war, and to which an approximate return may be expected after its close. In any case they may be readily corrected to meet local conditions.

Lime Nitrogen: 26 per cent ammonia. It is unquestionably the cheapest source of nitrogen (ammonia) in this country. The sales prices are dependent to an extent upon the quantities and deliveries contracted for. The freight is allowed at $3 per ton of Lime Nitrogen shipped in special containers, which should cover the greater portion of territory in the United States lying within a 500 mile haulage radius of Niagara.

Caustic Lime is to be air slacked on spot, 2 per cent weight Lime Nitrogen used assumed at $6 per ton delivered.

Soda Ash 3½ per cent of weight of Lime Nitrogen at $16 per ton delivered.

Power 100 horsepower continues at 1 cent per horsepower hour.

Steam at 30 cents per 1000 pounds, 60 per cent weight Lime Nitrogen.

Water 2 U. S. gallons per pound ammonia. As the larger part of this is used in condensers and coolers the greater proportion may be salt water. Assumed at 2 cents per M gallons.

Labor and Superintendence assumed at 300 men hours per day at 30 cents per man hour.

Repairs and Renewals $1.50 per ton ammonia, a record of long time operations.

Interest assumed at 6 per cent on plant cost of $120,000.

Depreciation on plant cost of $120,000 depreciated in 10 years, say 8 per cent.

OPERATING COST OF AMMONIA PLANT

Capacity 30,000 pounds ammonia per day, gas saturated with water at cooling water temperatures

Item.	Quantity.	Rate.	Per Day.	Per Pound Ammonia.
Freight	.....	$3.00	$180.00	$0.00600
Lime	1.20 tons	6.00	7.20	0.00024
Soda	2.10 tons	16.00	33.60	0.00112
Power	2400 H.P. hr.	.01	24.00	0.00080
Steam	72 M lbs.	.30	21.60	0.00072
Water	60 M gals.	.02	1.20	0.00004
Labor	300 men hrs.	.30	90.00	0.00300
Repairs and renewals	.....	.....	22.50	0.00075
Interest	.....	.....	20.00	0.00067
Depreciation	.....	.....	26.66	0.00089
Miscellaneous	.....	.....	24.67	0.00082
Total conversion cost, excluding NH_3 losses			$451.43	$0.01505

Cost of Plant: On account of the varied building conditions existing throughout the country it is almost impossible to give a detailed estimate of the cost of plant. A recent projection of such costs made by this Company for a plant of this size, from which I have deducted the cost of land, foundations and sludge disposal, shows that an ammonia plant of the size herein described could be erected for about $120,000. This plant is designed to produce an ammonia gas as its final product cooled to the temperature of the available water of the condensers, and, therefore, not strictly anhydrous. This figure further assumes that water and power are furnished the plant, and no provision is made for power or pumping plants.

Steel buildings with corrugated iron sides and roof, and of a type which have demonstrated themselves as fairly satisfactory for this service are included. The limitations imposed by building laws

and choice of architecture may force one materially to modify this estimate, as cheaper forms of construction may be used. On the other hand, many may prefer a more elaborate type of building than provided in the above estimate, which would materially raise this figure.

SUMMARY

The large number of installations operating with perfect success in various parts of the world for a number of years have demonstrated the commercial possibility of making ammonia from Lime Nitrogen. The plant in its present highly developed state is extremely certain in its action and simple to operate. The efficiency obtained in the transformation of the nitrogen in Lime Nitrogen into ammonia gas is upwards of 98 per cent, or almost quantitative. The consumption of reagents is remarkably small, and they are cheap and easy to obtain in almost all parts of the world.

The quality of the ammonia produced by this process is not surpassed by any in the United States. It is chemically pure as produced and requires no further costly and tedious purification to render it available for the highest grade chemical products, or for the production of liquefied anhydrous. The actual cost of production of this high grade pure ammonia on a considerable scale, which enables one to take advantage of the lower prices at which Lime Nitrogen is offered, brings high grade cyanamid-ammonia into the market almost as cheaply as the more impure forms already found there, and very much cheaper than it is possible to obtain an equal quality of ammonia from gas house liquor, the coke ovens, etc.

CONSTITUTION

ARTICLE I.

NAME.

This organization shall be termed,

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

ARTICLE II.

OBJECTS.

The objects of this organization shall be:

To advance the cause of applied chemical science.

To give the profession of Chemical Engineers such standing before the community as will justify its recognition by Municipal, State, and National authorities in public works.

To raise the professional standard among Chemical Engineers, discouraging and prohibiting unprofessional conduct.

To coöperate with educational institutions for the improvement of the education of the men who are to enter this profession.

To encourage original work in chemical technology.

To promote pleasant acquaintance and social and professional intercourse among its members.

To publish and distribute such papers as shall add to classified knowledge in chemical engineering and shall increase industrial activity.

ARTICLE III

MEMBERSHIP

SECTION 1. (*Qualifications for Membership.*) Membership shall consist of two grades: Active and Junior.

ACTIVE MEMBERSHIP shall require the following preparation and training:

All candidates must be not less than 30 years of age and must be proficient in chemistry and in some branch of engineering as applied to chemical problems, and must at the time of election be engaged actively in work involving the application of chemical principles to the arts. All candidates for admission to this Institute are expected to have *expert knowledge of at least one branch of applied chemistry.* and must fulfill one of the following requirements:

1. Candidates who hold no degree from an approved university or technical school must have had ten years' experience in chemical technology; five being in responsible charge of operations requiring the elaboration of raw materials, the design of machinery involving chemical processes, or the application of chemistry to industry.

2. Candidates who hold the degree of A. B. (Bachelor of Arts) from an approved university or technical school offering a four-year course must have had at least eight years of practical experience as outlined under No. 1.

3. Candidates who hold the degree of Ch. E. (Chemical Engineer), B. S. (Bachelor of Science), in Chemistry or Chemical Engineering, or E. E. (Electrical Engineer), C. E. (Civil Engineer), or M. E. (Mechanical Engineer), or equivalent degrees from an approved university or technical school offering at least a four-year course, must have had at least five years' practical experience as outlined under No. 1.

4. For candidates who in addition hold the degree of Ph. D. (Doctor of Philosophy) or Sc. D. (Doctor of Science) in Chemistry, the number of years required to earn the higher degree may be deducted from the number of years of experience required.

Junior Membership shall require the following preparation and training:

All candidates must be not less than 23 years of age and must be engaged, at the time of election, in some branch of applied chemistry and must fulfill one of the following requirements:

1. Hold the degree of Ch.E. (Chemical Engineer), B.S. (Bachelor of Science) in Chemistry or Chemical Engineering, E.E. (Electrical Engineer), C.E. (Civil Engineer), M.E. (Mechanical Engineer), or equivalent degree from an approved university or technical school offering at least a four years' course.

2. Have had five years' experience in Applied Chemistry.

Junior Members shall have all privileges of the Institute excepting those of voting, holding office, and wearing the emblem or badge of Active Membership. A suitable emblem or badge of Junior Membership as adopted by the Institute may be worn by the Junior Members. When qualified, a Junior Member may apply for Active Membership, but must do so before reaching the age of 35, otherwise his membership shall expire.

Section 2. (*Applications.*) All applications for membership must be made to the Secretary in writing, and shall embody a concise

statement with the dates of the candidate's professional training and experience, and shall be in a form and in such detail as may be prescribed by the Membership Committee. The applicant for Active Membership shall give the names of at least five members to whom he is personally known. The applicant for Junior Membership shall give the names of at least five persons to whom he is personally known, two of whom shall preferably be members of the Institute. Each of these shall be requested by the Secretary to certify to the training, experience, professional attainment, and standing of the applicant. On receiving a favorable report from at least three of these references, the applicant shall be eligible to recommendation by the Membership Committee.

Section 3. (*Election of Members.*) At stated periods the Secretary shall mail to the members a ballot containing a list of all applicants who have been recommended by the Membership Committee. This list shall contain a detailed statement of each applicant's career and the names of the members who have vouched for him. All ballots shall be returned to the Secretary not later than three weeks after the date of issue. The ballots shall be canvassed by the Membership Committee, who shall report to the Council, who shall then declare each applicant elected for whom at least ninety-five per cent. of all ballots cast are in the affirmative. Provided, however, that any member voting in the negative may address a confidential letter to the Council, stating his objections to the candidate with evidence for the charges made. If the Council upon investigation considers such objections valid, they may declare an election void. A rejected candidate may make application again any time after one year. Persons elected to membership shall be notified at once by the Secretary. They must then subscribe to the rules of the Institute.

Section 4. (*Honorary Members.*) As the result of unusual ability and public recognition on the part of the industrial world, a person may, upon nomination of the Council and a vote of the Society at large, be made an Honorary Member, but at no time shall this number exceed five.

Section 5. (*Expulsions.*) For abuse or misuse of the privileges of the Institute or conduct unbecoming a member in the opinion of the Council, a two-thirds vote of the Council may expel any member of the Institute.

Section 6. (*Dues.*) The entrance fee for Active Members shall be $15.00; Junior Members shall pay no entrance fee; Annual dues

for active members $15.00, for Junior Members $10.00. Junior Members, on becoming Active Members, shall pay an entrance fee of $15.00 less $1.00 per year for each year of their membership as Junior Members. Provided, however, that no entrance fee shall be exacted until the membership shall reach 200.

Any member may anticipate his dues for life by paying in advance such a sum as would be demanded by any reputable insurance association to yield an annuity equal to the annual dues from the time of the agreement until death. Upon resignation, or expulsion, all money so provided is to become the property of the Institute. Any person joining the Institute after the middle of the fiscal year is required to pay one-half of the dues only for that year. Any person in arrears for three months shall be notified by the Secretary. For non-payment at the expiration of one-half year, a member forfeits the right to vote or to receive the notices of the Association until dues are paid in full. Any member one year or more in arrears of dues may, on vote of the Council, be dropped from the Institute. All members are considered as such unless actual resignations are formally presented and accepted with the full payment of dues. On account of extenuating circumstances, dues may be remitted to any member by a two-thirds vote of the Council.

ARTICLE IV.

OFFICERS.

Section 1. The officers of this Society shall be a President, three Vice-Presidents, a Secretary, a Treasurer, an Auditor, and nine Directors. The officers shall be elected at the annual meeting. The President shall serve one year, the Vice-Presidents for three years each, and the Directors for three years each. The Secretary, Treasurer, and Auditor shall be elected for terms of one year each. At the first annual meeting one Vice-President shall be chosen for one year, one for two years, and one for three years. Three Directors shall be chosen for one year, three for two years, and three for three years. Thereafter, officers shall be chosen annually to serve full terms. The President, Ex-Presidents for the two years succeeding the expiration of their term of office as President, Vice-Presidents, Secretary, Treasurer, and Directors shall constitute the Council of the Institute. The President, Vice-Presidents, and Directors cannot be re-elected within the current twelve months from the expiration of term. The duties of office begin immediately

after election and notification. An acceptance of office must be in writing addressed to the Secretary. Vacancies occurring in any office shall be filled by a majority vote of the Council for the unexpired term. The duties of all officers shall be such as usually pertain to their offices or may be delegated to them by the Council or the Institute.

Section 2. (*Election of Officers.*) After the election at which this Constitution is adopted, the election of officers shall be by letter ballot. The Secretary, at least eight (8) weeks prior to each annual meeting, shall send to every member of the Institute a blank nominating ballot upon which the member may make nominations for the officers and Directors to be elected at the coming annual meeting. The nominating ballot is then to be properly signed and transmitted to the Secretary not later than five (5) weeks prior to the annual meeting. It shall then become the duty of the Secretary to prepare and issue an official ballot upon which shall appear the names of all nominations for office or for Directors which shall have appeared upon at least ten (10) nominating ballots. The official ballots shall be mailed not later than three (3) weeks prior to the annual meeting, one to each member, who shall properly signify on it his choice for the various offices and Directors, and transmit it to the Secretary. At the annual meeting the President shall appoint tellers to whom the Secretary shall deliver all the ballots received by him unopened, and who shall count and announce the vote.

ARTICLE V

COUNCIL

The Council shall have supervision and care of all property of the organization, and shall conduct its affairs according to the Constitution and By-Laws. At each annual meeting it shall present a statement of its proceedings during the year. Eight members of the Council called together by notice from the Secretary shall constitute a quorum, provided, however, that three members may be represented by proxy.

ARTICLE VI.

STANDING COMMITTEES.

The Council shall appoint the following committees:

1. FINANCE.
2. COMMITTEE ON MEETINGS.
3. PUBLICATIONS.

4. Membership.
5. Library.
6. House Committee.

FINANCE COMMITTEE.

The Finance Committee shall have charge of the financial affairs of the Institute. This committee must prepare the budget and approve all expenditures. The Chairman of the Committee may be the Auditor of the Institute.

MEMBERSHIP COMMITTEE.

The Membership Committee shall be constituted of fifteen members, ten of whom may vote by proxy at any meeting. To the Membership Committee all applications for membership shall be referred. It is the duty of this committee to see that no person is admitted to the organization who is not qualified.

COMMITTEE ON MEETINGS.

This committee shall have charge of all meetings of the organization and shall fix dates and places of meeting.

COMMITTEE ON PUBLICATIONS.

This committee shall look after the papers presented to the Institute. If considered expedient, any or all of these papers may be published and distributed to members.

LIBRARY COMMITTEE.

This committee shall have charge of all permanent records, books, papers, pamphlets, etc., and shall obtain and place on file a complete record of all patent literature in reference to chemical engineering.

HOUSE COMMITTEE.

This committee shall look after the social affairs of the Institute, fixing the time and place of entertainments.

ARTICLE VII.

MEETINGS.

The annual meeting of the Association shall be held in December, the exact date to be fixed by the Council.

This Institute shall be governed by its Constitution in conformity with the laws of the United States. All questions shall be decided by majority of votes cast. The Institute shall not be held

responsible for opinions expressed in papers. The name or use of the Institute shall not be tolerated for any commercial purpose.

Upon the adoption of this Constitution officers shall be elected immediately to hold office until the election and installation of their successors.

ARTICLE VIII.

AMENDMENTS TO THE CONSTITUTION.

Any member may propose an amendment by addressing the Secretary. At the first regular meeting thereafter the subject shall be discussed, and if worthy, notice to vote on same shall be posted until the next regular meeting, and written copy of the notice shall be sent to each member. The proposed amendment shall then be discussed in open meeting and can be passed by two-thirds vote of all members of the Institute as the result of letter ballot.

BY-LAWS

ORDER OF BUSINESS.

REGULAR MEETING.

Reading of minutes of last stated meeting.
Miscellaneous announcements.
Reading of papers, discussion, and communications.
Adjournment.

ANNUAL MEETING.

Reading of minutes of last stated meeting.
Miscellaneous announcements.
Stated business.
Annual reports.
Election of officers.
Address of retiring President, etc.
Adjournment.

In all questions requiring parliamentary ruling not provided for by the Rules of the Institute, "Robert's Rules of Order" shall be the governing authority.

CODE OF ETHICS

ARTICLE I.

PURPOSE OF THE CODE:

To define the rules of professional conduct and ethics for the members of the Institute.

ARTICLE II.

THE INSTITUTE EXPECTS OF ITS MEMBERS:

1st. That in all their relations, they shall be guided by the highest principles of honor.

2d. The upholding before the public at all times of the dignity of the chemical profession generally and the reputation of the Institute, protecting its members from misrepresentation.

3d. Personal helpfulness and fraternity between its members and toward the profession generally.

4th. The avoidance and discouragement of sensationalism, exaggeration and unwarranted statements. In making the first publication concerning inventions or other chemical advances, they should be made through chemical societies and technical publications.

5th. The refusal to undertake for compensation work which they believe will be unprofitable to clients without first advising said clients as to the improbability of successful results.

6th. The upholding of the principle that unreasonably low charges for professional work tend toward inferior and unreliable

work, especially if such charges are set at a low figure for advertising purposes.

7th. The refusal to lend their names to any questionable enterprise.

8th. Conservatism in all estimates, reports, testimony, etc.. especially in connection with the promotion of business enterprises.

9th. That they shall not engage in any occupation which is obviously contrary to law or public welfare.

10th. When a chemical engineer undertakes for others work in connection with which he may make improvements, inventions, plans, designs or other records, he shall preferably enter into a written agreement regarding their ownership. In a case where an agreement is not made or does not cover a point at issue, the following rules shall apply:

a—If a chemical engineer uses information which is not common knowledge or public property, but which he obtains from a client or employer, any results in the form of plans, designs or other records shall not be regarded as his property, but the property of his client or employer.

b—If a chemical engineer uses only his own knowledge or information or data, which by prior publication or otherwise are public property, and obtains no chemical engineering data from a client or employer except performance specifications or routine information, then the results in the form of inventions, plans, designs or other records should be regarded as the property of the engineer and the client or employer should be entitled to their use only in the case for which the engineer was retained.

c—All work and results accomplished by the chemical engineer in the form of inventions, plans, designs or other records, or outside of the field for which a client or employer has retained him, should be regarded as the chemical engineer's property.

d—When a chemical engineer participates in the building of apparatus from designs supplied him by a client, the designs remain the property of the client and should not be duplicated by the engineer nor anyone representing him for others without express permission.

e—Chemical engineering data or information which a chemical engineer obtains from his client or employer or which he

creates as a result of such information must be considered confidential by the engineer; and while he is justified in using such data or information in his own practice as forming part of his professional experience, its publication without express permission is improper.

f—Designs, data, records and notes made by an employee and referring to his employer's work, should be regarded as his employer's property.

g—A client does not acquire any exclusive right to plans or apparatus made or constructed by a consulting chemical engineer except for the specific case for which they were made.

11th. A chemical engineer cannot honorably accept compensation, financial or otherwise, from more than one interested party, without the consent of all parties; and whether consulting, designing, installing or operating, must not accept compensation directly or indirectly from parties dealing with his client or employer.

When called upon to decide on the use of inventions, apparatus, processes, etc., in which he has a financial interest, he should make his status in the matter clearly understood before engagement.

12th. The chemical engineer should endeavor at all times to give credit for work to those who, so far as his knowledge goes, are the real authors of such work.

13th. Undignified, sensational or misleading advertising is not permitted.

14th. Contracts made by chemical engineers should be subject to the Code of Ethics unless otherwise specified.

ARTICLE III.

For the administration of this Code of Ethics, a Committee on Ethics shall be appointed by the president holding office at the time of the adoption of this Code with the approval of the Council, to consist of five members; one appointed for five years, another for four years, another for three years, another for two years, another for one year, and thereafter, the president then holding office shall appoint one member annually to serve for five years and also fill such vacancies as may occur for an unexpired term. All of these members shall be over forty years of age. The Committee shall elect its own chairman. The Committee on Ethics shall investigate all complaints submitted to them bearing upon the professional con-

duct of any member, and after a fair opportunity to be heard has been given to the member involved, shall report its findings to the Council, whose action shall be final.

ARTICLE IV.

Amendments.

Additions to or modifications of this Code may be made according to Article VIII of the Constitution.

OFFICERS AND COMMITTEES FOR 1916

COUNCIL

Elected at Baltimore Meeting, January 12, 1916

President,

Geo. D. Rosengarten..... Philadelphia, Pa.

Vice-Presidents,

G. W. Thompson..... Brooklyn, N. Y.
A. C. Langmuir..... Brooklyn, N. Y.
John M. Stillman..... Stanford Univ., Cal.

Secretary,

John C. Olsen..... Brooklyn, N. Y.

Treasurer,

F. W. Frerichs..... St. Louis, Mo.

Auditor,

H. C. Chute..... New York, N. Y.

Ex-Presidents,

T. B. Wagner..... New York, N. Y.
M. C. Whitaker..... New York, N. Y.

Directors for One Year

Henry Howard..... Boston, Mass.
John C. Hebden..... Providence, R. I.
Iens P. Lihme..... Cleveland, O.

Directors for Two Years

Geo. P. Adamson..... Easton, Pa.
J. B. F. Herreshoff..... New York, N. Y.
Samuel P. Sadtler..... Philadelphia, Pa.

Directors for Three Years

A. D. Little..... Boston, Mass.
Chas. F. McKenna..... New York, N. Y.
Richard K. Meade..... Baltimore, Md.

COMMITTEE ON PUBLICATIONS

Olsen, J. C., *Chairman*
Gray, Chas. W.
Hart, Edw.
Bain, J. W.
Ittner, M. H.
Cushman, A. S.
Miner, H. S.

MEMBERSHIP COMMITTEE

Langmuir, A. C., *Chairman*
Ittner, M. H.
Adamson, Geo. P.
Kaufmann, H. M.
Baruch, E.
Meade, R. K.
Bassett, W. H.
Miner, H. S.
Converse, W. A.
Richards, J. W.
Chute, H. O.
Thompson, G. W.
DeCew, J. A.
Withrow, J. R.

CHAIRMEN OF LOCAL COMMITTEES ON MEMBERSHIP

Frerichs, F. W.	St. Louis, Mo.
Belden, A. W.	Pittsburgh, Pa.
Lihme, I. P.	Cleveland, O.
Miner, H. S.	Gloucester City, N. J.
Parker, T. J.	New York, N. Y.
Little, A. D.	Boston, Mass.
Converse, W. A.	Chicago, Ill.

COMMITTEE ON CHEMICAL ENGINEERING EDUCATION

Withrow, Jas. R., *Chairman*
Sadtler, S. P.
Hart, Edw.
Little, A. D.
Wagner, T. B.
Whitaker, M. C.

COMMITTEE ON MEETINGS

Sadtler, S. S., *Chairman*
Booth, Wm. M.
Ittner, M. H.
Langmuir, A. C.
Olsen, J. C.
Lidbury, F. A.
Lihme, I. P.
Meade, R. K.

FINANCE COMITTEE

Toch, Maximilian
Catlin, C. A.
Zinsser, F. G.

COMMITTEE ON MEDAL

Booth, Wm. M., *Chairman*
Richards, J. W.
Reese, Chas. L.
Sadtler, S. P.

LIBRARY COMMITTEE

ALEXANDER, JEROME, *Chairman* — OLSEN, J. C.
MYERS, R. E.

COMMITTEE ON PATENTS

BAEKELAND, L. H., *Chairman* — GROSVENOR, WM. M.
TOCH, MAXIMILIAN — LEE, F.

COMMITTEE ON PUBLIC POLICY

MCKENNA, CHAS. D., *Chairman* — FRERICHS, F. W.
BAEKELAND, L. H. — WHITAKER, M. C.
SADTLER, S. P. — WAGNER, T. B.

COMMITTEE ON CATALOGUES

MCKENNA, CHAS. F., *Chairman* — WHITAKER, M. C.
BAEKELAND, L. H.

COMMITTEE ON ETHICS

THOMPSON, G. W., *Chairman*, 3 yrs. — WHITAKER, M. C., 2 yrs.
MCKENNA, CHAS. F., 1 yr. — HEBDEN, J. C., 4 yrs.

LIST OF MEMBERS, AUGUST, 1916

Honorary Member

CHANDLER, CHAS. F., Columbia University, New York City.

Active Members

ACHESON, EDWARD G., 35 West 42d St., New York, N. Y.
President, Acheson Corporation.

ADAMSON, GEORGE P., 233 Reeder St., Easton, Pa.
Vice-President and General Manager, The Baker and Adamson Chemical Co.

ADGATE, MATTHEW, Naugatuck, Conn.
Supt. of the Naugatuck Chemical Co.

ALEXANDER, D. B. W., c/o Barber Asphalt Paving Co., Maurer, N. J.

ALEXANDER, JEROME, 59th St. & 11th Ave., New York, N. Y.
Treasurer and Chemist, National Gum & Mica Co., National Glue & Gelatin Works.

ALLEN, LUCIUS, E., New Bank of Commerce Bldg., Belleville, Ont., Can.
Consulting Chemical Engineer; Managing Director Ontario Limestone and Clay Co., Ltd., Belleville, Ont.

ANDERSON, LOUIS J., 129 Lafayette St., Easton, Pa.
Chemical Engineer, Alpha Portland Cement Co., Easton, Pa.

ANDREWS, LAUNCELOT W., 6547 Stewart Ave., Chicago, Ill.
Victor Chemical Works, Chicago Heights, Ill.

ANSBACHER, LOUIS A., 527 Fifth Ave., New York, N. Y.
A. B. Ansbacher & Co.

ARNOLD, CHARLES E., 602 West 20th St., Wilmington, Del.

AUSTIN, HERBERT, 485 North Main St., Fall River, Mass.
Chemical Engineer and Partner Manager of Ernest Scott & Co., of Fall River, Mass., and Montreal, P. Q.

AYER, ARTHUR W., 216 South Ashland Ave., La Grange, Ill.

BACON, RAYMOND, F., Pittsburg, Pa.
Director of the Mellon Institute of Industrial Research and School of Specific Industries of the University, and Dean of the School of Chemistry of the University of Pittsburg.

BAEKELAND, LEO H., Yonkers, N. Y.
Research Chemist and Chemical Engineer.

BAIN, J. WATSON, University of Toronto, Toronto, Can.
Associate Professor of Applied Chemistry.

BAIRD, WM. H., 1199 Woodward Ave., Detroit, Mich.
Gen. Mgr., The Garden City Sugar and Land Co., Garden City, Kan.

BAKER, JOHN T., Phillipsburg, N. J. President, J. T. Baker Chemical Co.

BARR, WM. M., Consulting Chemist, Union Pacific R.R., Omaha, Neb.

BARTON, G. E., 227 Pine St., Millville, N. J.
In charge of Laboratory and Dept. Mfg. Glass, Whitall Tatum Co.

BARUCH, EDGAR, 806 Wright & Callender Bldg., Los Angeles, Cal.
Consulting Chemical Engineer.

BARTOW, EDWARD, Urbana, Ill.
Professor of Analytical Chemistry, Univ. of Ill.; Director of State Water Survey of Illinois; Consulting Chemist with the Davenport Water Co.

BASKERVILLE, CHAS., 611 W. 110th St., New York, N. Y.
Professor of Chemistry, and Director of the Laboratory, College of City of New York; Chemical Inventor.

BASSETT, WILLIAM H., Cheshire, Conn. Metallurgist, American Brass Co.

BEBIE, J., 1800 South 2d St., St. Louis, Mo.
Chemical Engineer, Monsanto Chemical Works.

BECK, ARTHUR G., c/o Canada Cement Co., Exchaw, Alberta, Canada.
Supt., Plant 12.

BECNEL, LEZIN A., 1510 Arabella St., New Orleans, La., P. O. Box 649.
Chemical Engineer and Consulting Chemist.

BEERS, FRANK T., Washburn, Wis.
Supt. Barksdale Plant, E. I. du Pont de Nemours Powder Co.

BEHREND, OTTO F., Erie, Pa.
Vice-President and Treasurer, Hammermill Paper Co.

BELDEN, A. W., c/o Jones & Laughlin Steel Co.,
Aliguippa Works, Woodlawn, Pa.

BERG, HOLGER V., Newport, Del.
Superintendent and Vice-President of The Krebs Pigment & Chemical Co., Newport, Del.

BOOTH, L. M., 58 Hudson St., Jersey City, N. J.
President and Director, L. M. Booth Co., New York, N. Y.

BOOTH, WILLIAM M., Dillaye Building, Syracuse, N. Y.
299 Broadway, New York, Consulting Chemist and Engineer.

BOWER, WILLIAM H., 2815 Gray's Ferry Rd., Philadelphia, Pa.
First Vice-President of Henry Bower Chemical Mfg. Co.

BRAGG, CHAS. T., Mansfield, O. Chemical Engineer, Ohio Brass Co.

BRAGG, E. B., Evanston, Ill.
Vice-President and Manager of General Chemical Co., Chicago Branch.

BROOKS, PERCIVAL C., General Chemical Co., Chicago Heights, Ill.
Asst. Supt., Illinois Works, General Chemical Co., Chicago Heights, Ill.

BURNS, DEANE, 2072 Warren Road, Lakewood, O.
Chemical Engineer, Harshaw Fuller & Goodwin Co.

CAMP, J. M., Chief Bureau of Instruction, Carnegie Steel Co., Carnegie Bldg., Pittsburgh, Pa.

CARNELL, WILLIAM C., 3500 Gray's Ferry Road, Philadelphia, Pa.
Chemical Director Harrison Bros. & Co., Inc.

*Catlin, Charles A., 133 Hope St., Providence, R. I.
Chief Chemist and a Director of the Rumford Chemical Works.

Chute, Harry O., 197 Pearl St., New York. Chemical Engineer.

Clark, William, M., 71 Allandale Ave., E. Cleveland, O.
Mgr. Euclid Glass Div., General Electric Co., Cleveland, O.

Clymer, W. R., 13985 Lake Ave., Cleveland, O.
Factory Mgr., National Carbon Co., Cleveland, O.

Comey, A. M., Drawer 424, Chester, Pa.
Director Eastern Laboratory, E. I. du Pont de Nemours Powder Co.

Converse, William A., 2005 McCormick Building, Chicago, Ill.
Chemical Director Dearborn Drug and Chemical Works.

Conner, Arthur B., 217 W. Boulevard, Detroit, Mich.
Chief Chemist and Chemical Engineer for Detroit Chemical Works, Detroit, Mich.

Corse, Wm. M., 106 Morris Ave., Buffalo, N. Y.
Mgr. Bronze Dept., The Titanium Alloy Mfg. Co., Niagara Falls, N. Y.

Cross, Ed. O., Nela Park, Cleveland, O.
Mgr., Glass Works, National Lamp Works of General Electric Co.

Crowley, Chas. F., Omaha, Neb.
Gas Commissioner of the City of Omaha, Neb.; Professor of Chemistry, Creighton Medical College.

Cushman, Allerton S., 19th and B Sts., N. W., Washington, D. C.
Director and President, Institute of Industrial Research.

Dailey, J. G., c/o Crown Cork and Seal Co., Baltimore, Md.

Dannenbaum, Herman, Frankford, Philadelphia, Pa.
Vice-President National Ammonia Co.

Davoll, David, Jr., 765 Westminster Road, Brooklyn, N. Y.
Chief Chemist, Henry Heide, 313 Hudson St., New York, N. Y.

Dean, John G., 419 N. Central Ave., Glendale, Cal.
Southwestern Portland Cement Co.

DeCew, J. A., Canadian Express Bldg., Montreal, Canada.
Consulting Chemical Engineer.

Dill, Colby, 161 Rahway Ave., Woodbridge, N. J.
Works Manager, Perth Amboy Chemical Works, Perth Amboy, N. J.

Dorr, John V. N., 17 Battery Place, New York, N. Y.
President and General Manager, The Dorr Cyanide Machinery Co.
Consulting metallurgical engineer.

Dorsey, F. M., 1943 E. 107th St., Cleveland, O.
General charge of Lamp Development Lab. of National Quality Division of the General Electric Co., Cleveland, O.

Dow, A. W., 131 E. 23d St., New York, N. Y.
Member of the firm of Dow & Smith, Consulting Engineers.

Duperu, Alphonse M., Crockett, Cal.
Assistant Manager, California & Hawaiian Sugar Refining Co.

Drefahl, Louis Charles, 3132 W. 15th St., Cleveland, O.
Research Dept., The Grasselli Chemical Co., Cleveland, O.

* Deceased April 12, 1916

ELDRED, FRANK R., c/o Eli Lilly & Co., Indianapolis, Ind.
Chief Chemist and Director of the Scientific Division, Eli Lilly & Co.

ELLIOT, A. H., 52 E. 41st St., New York, N. Y. Consulting Engineer.

ELLIS, CARLETON, 92 Greenwood Ave., Montclair, N. J.
Consulting Chemist and Inventor.

FAIRLIE, ANDREW M., Copperhill, Tenn.
Supt. Acid Mfg. Dept., Tennessee Copper Co.

FLORA, CHAS. P., 55 Marshall St., Watertown, Mass.
Chemical Engineer, Hood Rubber Co., Watertown, Mass.

FOERSTERLING, HANS, 380 High St., Perth Amboy, N. J.
Second Vice-President, Roessler & Hasslacher Chemical Co.

FOWLER, THEODORE V., 25 Broad St., New York, N. Y.
General Chemical Co.

FRENCH, EDW. H., Smethport, Pa.
Chemical Engineer, Hilton & French, Smethport Research and Testing Laboratories.

FRERICHS, F. W., 4320 Washington Bou., St. Louis, Mo.
Vice-President, Herf & Frerichs Chemical Co.

GAYLEY, JAS., 71 Broadway, New York, N. Y.
Sheffield Coal and Iron and American Ore Reclamation Co.

GIBBS, A. E., c/o Pennsylvania Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

GLOVER, H. LESTER, 73 W. Johnson St., Germantown, Phila., Pa.
Supt. of the Falls of Schuylkill Works of the Powers-Weightman-Rosengarten Co.

GOULD, RALPH A., 216 Pine St., San Francisco, Cal.
Member of the firm, Gould & Ash, Chemical Engineers, San Francisco, Cal.

GRAVES, WALTER, G., 1950 E. 90th St., Cleveland, O.
Mfg. Dept., Grasselli Chemical Co., Cleveland, O.

GRAY, CHAS. W., Sinnamahoning, Pa.
Supt., Sinnamahoning Plant, Aetna Explosives Co., Inc., Sinnamahoning, Pa.

* GRETH, J. C. WM., Pittsburgh, Pa.
Manager, Water Purifying Dept. of William B. Scaife & Sons Co.

GRISWOLD, THOMAS, Jr., Midland, Mich.
Engineer, The Dow Chemical Co.; Secretary, The Midland Chemical Co.

GROVE, S. FELTON, 2815 Gray's Ferry Rd., Philadelphia, Pa.
Supt. Detinning Dept., Henry Bower Chemical Mfg. Co., Philadelphia, Pa.

GROSVENOR, WM. M., 50 E. 41st St., New York City.
Consulting Chemist and Factory Engineer.

GUDEMAN, EDWARD, 903–4 Postal Telegraph Bldg., Chicago, Ill.
Consulting Chemist and Chemical Engineer.

HAANEL, BENJAMIN F., 236 1st Ave., Ottawa, Ont., Canada.
Chief Engineer of the Division of Fuels and Fuel Testing, Mines Branch, Dept. of Mines, Ottawa, Canada.

* Deceased, Aug. 7, 1915.

HAANEL, EUGENE, Dept. of Mines, Ottawa, Ont., Can.
Director of Mines, Dept. of Mines, Ottawa, Ont., Can.

HANNA, WILSON C., Colton, Cal.
Chief Chemist and Chem. Eng., California Portland Cement Co.

HART, EDWARD, Easton, Pa.
Professor Chemistry, Lafayette College, President of Hart Chemical Corporation; Prop. Chem. Pub. Co.; Consulting Eng. Dean Pardee Scientific Dept., Librarian Oliver Library, Lafayette College; Vice-pres. Clinchfield Products Corp.

HEBDEN, JOHN C., 30 Pine St., New York, N. Y.
Vice-President, Federal Dyestuff & Chemical Co.

HERRESHOFF, J. B. FRANCIS, 620 West End Ave., New York, N. Y.
Vice-President Nichols Copper Co.; Consulting Engineer, General Chemical Co.

HOLLAND, WM. R., Gloucester City, N. J.
Foreman of the Chemical Dept., Welsbach Light Co., and Assistant to Chief Chemist.

HOLLANDER, CHARLES S.,
Chemist, Rohm & Haas, 2522 S. Western Ave., Chicago, Ill.

HOLTON, EDWARD C., 601 Canal Road, N. W., Cleveland, O.
Chief Chemist, The Sherwin-Williams Co.

HOOKER, ALBERT H., Niagara Falls, N. Y.
Tech. Dir., Hooker Electrochemical Co., Niagara Falls, N. Y.

HOSKINS, WM., 111 W. Monroe St., Chicago, Ill.
Mariner & Hoskins, Consulting Chemical Engineers.

HOWARD, HENRY, 33 Broad St., Boston, Mass.
Vice-President, Merrimac Chemical Co.

HUGHES, L. S., 2130 Sedgewick St., Chicago, Ill.
Chemist, Illinois Steel Co.

* HUMPHREY, H. C., 17 Battery Pl., New York City.
Chief Chemist, Eastern Branch, Corn Products Refining Co.

ITTNER, MARTIN H., Colgate & Co., Jersey City, N. J.
Chief Chemist, Colgate & Co.

JAMES, JOSEPH H., Pittsburgh, Pa.
Prof. Chemical Engineering Practice, Carnegie Technical Schools.

JAYNE, DAVID W., c/o Barrett Mfg. C., 17 Battery Place, New York, N. Y.
Manager Chemical Dept., Barrett Mfg. Co.

JONES, A. B., 981 Central Ave., Plainfield, N. J.
Supt. Laurel Hill and Bayonne Works, General Chemical Co.

JONES, L. C., Syracuse, N. Y.
Laboratory Manager, Solvay Process Co., and Semet Solvay Co.; Vice-President, Solvay Colleries Co.

JOYCE, CLARENCE M., c/o J. Merritt Matthews, 50 E. 41st St., New York. N. Y.
Consulting Chemist to the Nitrocellulose Industries.

* Deceased, Jan. 9, 1916.

KALMUS, HERBERT T., 156 6th St., Cambridge, Mass.
Consulting Chemical and Metallurgical Engineer, Vice-President and Treasurer, The Exolon Co., 156 6th St., Cambridge, Mass., Thorold, Ont., Blasdell, N. Y. President Kalmus, Comstock & Wescott, Inc., Boston, Mass.

KAUFMANN, H. M., 55 John St., New York, N. Y.
General Manager, Mutual Chemical Co. of America.

KESSLER, JOHN J., 224 S. Vandeventer Ave., St. Louis, Mo.
President and General Mgr. of The Dielectric Mfg. Co., also Chemical Engineer.

KILMER, FREDERICK BARNETT, 147 College Ave., New Brunswick, N. J.
Director of Laboratories, Johnson & Johnson, New Brunswick, N. J.

KIMMEL, H. R., 18725 Sloane Ave., Lakewood, O.
Consulting Chemical Engineer, Industrial Testing Laboratory.

KINGSBURY, PERCY C., 50 Church St., New York, N. Y.
Chief Engineer, German-American Stoneware Works, 50 Church St., New York City.

KIPPENBERG, HENRY, 15 Darmstadt Ave., Rahway, N. J.
Supt. of Chemical Manufacture at Rahway Plant of Merck & Co.

KRAUSE, ALBERT H., 1444 West 98th St., Cleveland, O.
Division Supt., The American Agricultural Chem. Co.

KREMER, WALDEMAR R., Vilter Mfg. Co., Milwaukee, Wis.
Electrical-Mechanical Engineer.

LAMAR, WILLIAM ROBINSON, 327 North 18th St., East Orange, N. J.
General Sales Manager, Lamar Chemical Works.

LANDIS, W. S., Room 548, 200 Fifth Ave., New York City.
Chief Technologist, American Cyanamid Co., Niagara Falls, N. Y.

LANGMUIR, ARTHUR C., 9 Van Brunt St., Brooklyn, N. Y.
Supt. Factory, Marx & Rawolle.

LARKIN, E. H., 3600 N. Broadway, St. Louis, Mo.
Director, National Ammonia Co., St. Louis, Mo.

LAZELL, E. W., 426 Railway Exchange Bldg., Portland, Ore.
Edwards & Lazell, Consulting and Chemical Engineers

LEBLANC, E. M., ARGUELLES 145, Cienfuegos, Cuba.
Engineer, Cienfuegos, Cuba.

LEE, FITZHUGH, Grasselli Chemical Co., Cleveland, Ohio.
Assistant Chairman Manufacturing Committee, Grasselli Chemical Co.

LE MAISTRE, F. J., Ridley Park, Del. Co., Pa.
Chemical Engineer, E. I. du Pont de Nemours Powder Co.

LESSNER, CHAS., Carril, Spain.
Manager of the Carril Works and Chemist to the San Finx Tin Mines, Ltd., and Metallurgical Chemist to the Angelita Mines.

LE SUEUR, ERNEST A., 50 McLaren St., Ottawa, Ont., Canada.
General Manager and President of the General Explosives Co., Ltd.

LIDBURY, F. A., Niagara Falls, N. Y.
Works Manager, Oldbury Electro-chemical Co., Niagara Falls, N. Y.

LIHME, IENS P., Grasselli Chemical Co., Cleveland, Ohio.
Engineer, Grasselli Chemical Co.

LIHME, C. BAI, 1350 North State St., Chicago, Ill.
Director Matthiessen & Hegeler Zinc Co., La Salle, Ill., President, La Salle & Bureau County R.R. Co., President, Industrial Research Laboratories, Danville, Ill.

LITTLE, A. D., 93 Broad St., Boston, Mass.
President and General Manager, Arthur D. Little, Inc., Chemists and Engineers; President and General Manager, Chemical Products Co., Boston, Mass.

LOVE, EDWARD G., 130 E. 15th St., New York, N. Y.
Chief Chemist, Consolidated Gas Company of New York.

LUNDTEIGEN, A., c/o Ash Grove Lime and Portland Cement Co., Kansas City, Mo.
Managing Engineer, Ash Grove Lime and Portland Cement Co., Kansas City, Mo.

MALINOVSZKY, ANDREW, Lincoln, Ill.
Chief Chemist for the American Brick Co.

MALLINCKRODT, EDWARD, St. Louis, Mo.
President Mallinckrodt Chemical Works.

MARSH, CLARENCE W., 201 Devonshire St., Boston, Mass.
Consulting and Chemical Engineer.

MARSHALL, ALBERT E., 50 East 41st St., New York, N. Y.
General Manager and Designer of Chemical Plant, Thermal Syndicate, New York, N. Y.

MASON, WILLIAM P., Troy, N. Y.
Prof. Chemistry, Rensselaer Polytechnic Institute.

MATOS, LOUIS J., 103 No. 19th St., E. Orange, N. J.
Technical Chemist and Chemical Engineer with the Cassella Color Co., 182 Front St., New York City.

MATTHEWS, J. M., 5 Berwyn St., East Orange, N. J.
Consulting Chemist, especially to the textiles industries.

MACNAUGHTON, WM. G., Port Edwards, Wis.
Assistant to General Manager in charge of manufacturing, Nekoosa Edwards Paper Co.

MCCORMACK, HARRY, Armour Institute, Chicago, Ill.
Professor of Chemical Engineering, Armour Institute of Technology, Chicago, Ill.; Editor of the Chemical Engineer; Consulting Chemist and Chemical Engineer.

MCKENNA, CHAS. F., 50 Church St., New York, N. Y.
Consulting Chemist and Chemical Engineer.

MEADE, RICHARD K., Roland Park, Baltimore Co., Md.
Consulting Chemical Engineer.

MEAD, GEO. P., Cardenas, Cuba.
Supt. Cardenas Refinery, Cardenas, Cuba; Ass't Chief Chemist, Cuban-American Sugar Co.

METZ, Gustave P., 440 West End Ave., New York, N. Y.
Superintendent and Vice-President, Consolidated Color and Chemical Co., 122 Hudson St., New York, N. Y.

MINER, H. S., Gloucester City, N. J. Chief Chemist Welsbach Light Co.

MINOR, JOHN C., Jr., Elizabeth, N. J. Manager, General Carbonic Co.

MITCHELL, J. PEARCE, Stanford University, Cal.
Assistant Professor of Chemistry at Stanford University.

MONK, R. H., 388 Grosvenor Ave., Westmount, Can.
Chem. Eng and Mgr. of Lead Works for Brandram-Henderson Ltd., Montreal.

MURRILL, PAUL I., Kingsport, Tenn. Federal Dyestuff & Chemical Co.

MYERS, RALPH E., 31 Franklin Ave., East Orange, N. J.

NEWHALL, CHAS. A., 1810 Westlake Ave., Seattle, Wash.
Chemical Engineer, Charles A. Newhall Co., Seattle, Wash.

OLNEY, LOUIS A., Lowell Textile School, Lowell, Mass.
Professor of Chemistry and Head of the Department of Textile Chemistry and Dyeing, Lowell Textile School; President Stirling Mills, Lowell, Mass.

OLSEN, JOHN C., Cooper Union, New York.
Prof. of Chemistry and Head of the department; Consulting Chemist.

O'NEILL, EDMOND, University of California, Berkeley, Cal.
Professor of Chemistry, University of California.

PALMER, CHAS. S., Mellon Institute of Industrial Research, Pittsburg, Pa.

PARKER, THOS. J., 92 William St., New York, N. Y.

PARR, S. W., Urbana, Ill.
Professor of Applied Chemistry, University of Illinois, Urbana, Ill.

PECKHAM, STEPHEN F., 1154 Sterling Pl., Brooklyn, N. Y.

PHILIPP, HERBERT, 152 High St., Perth Amboy, N. J.
Research Chemist, Roessler & Hasslacher Chem. Co.

PORTER, J. EDWARD, Box 785, Syracuse, N. Y. Chemical Engineer.

PRENTISS, GEORGE N., 225 34th St., Milwaukee, Wis.
Chief Chemist, C., M. & St. P. R. R.

PROCHAZKA, GEORGE A., 138 West 13th St., New York.
General Manager, Central Dyestuff Chemical Co., Newark, N. J.

PUCKHABER, GEO. C., 1140 President St., Brooklyn, N. Y.

REESE, CHARLES LEE, 725 du Pont Building, Wilmington, Del.
Chemical Director, High Explosives Operating Dept., E. I. du Pont de Nemours Powder Co.

RIGG, GILBERT, Palmerton, Pa.
Chief of Research Dept., and Sales Engineer to the New Jersey Zinc Co., 55 Wall St., New York, N. Y.

RICHARDS, J. W., University Park, South Bethlehem, Pa.
Professor of Metallurgy, Lehigh University; Secretary American Electrochemical Society; President Electrochemical Publishing Co.

RICHARDSON, WM. D., Swift & Co., Chicago, Ill.
Chief Chemist and Chemical Engineer.

RITTMAN, WALTER FRANK, Empire Building, Pittsburgh, Pa.
Mgr. Rittman Process Corp., Pittsburgh, Pa.

ROESSLER, FRANZ, 89 High St., Perth Amboy, N. J.
Vice-President, and Secretary, Roessler & Hasslacher Chemical Co.

ROSENGARTEN, GEO. D., Box 1625; Philadelphia, Pa.
Vice-President, The Powers-Weightman-Rosengarten Co.

SADTLER, SAMUEL P., 210 So. 13th St., Philadelphia, Pa.
Prof. Chemistry Philadelphia College of Pharmacy and Consulting Chemist. Samuel P. Sadtler & Son.

SADTLER, SAMUEL S., 210 So. 13th St., Philadelphia, Pa.
Samuel P. Sadtler & Son.

SCHANCHE, H. G., 3500 Gray's Ferry Road, Philadelphia, Pa.
Chemical Director, Harrison Bros. & Co., Inc., Philadelphia, Pa.

SCHMIDT, W. A., 1016 W. 9th St., Los Angeles, Cal.
President and General Manager, Western Precipitation Co.; President International Precipitation Co.

SCHROEDER, C. M. EDW., Rutherford, N. J.
Consulting Chemist, 34 Bloomfield Ave., Passaic, N. J.

SHARPLES, STEPHEN P., 26 Broad St., Boston, Mass.
Analytical and Consulting Chemical Engineer and Assayer.

SHATTUCK, A. FORREST, Detroit, Mich. Chief Chemist, Solvay Process Co.

SHIMER, PORTER W., Easton, Pa.
Proprietor and Chief Chemist of Chemical Laboratory.

SIMMONS, W. H., Fenton, Mich.
Superintendent, New Aetna Portland Cement Co.

SIMPSON, EDWARD H., Mutual Chemical Co., of America, Westside Ave. Jersey City, N. J. Mgr. Arlington plant.

SMITH, ALBERT W., 11333 Bellflower Rd., Cleveland, O.
Professor of Chemistry and Director of the Chemical Laboratory of Case School of Applied Science.

SMITH, FRANCIS PITT, 131–133 East 23d St., New York, N. Y.
Member of the firm of Dow & Smith, Chemical Engineers.

SMITH, HARRY E., 36 Beeresford Pl., East Cleveland, Ohio.
Chemist and Engineer of Tests, Lake Shore & Michigan Southern Ry.

SMITH, MORGAN B., 371 Atwater St., East Detroit, Mich.
Chief of Testing Dept., Stirne Engineering Co., Detroit, Mich.

STARK, ARTHUR L., Elyria, O.
Vice-Pres. & Mgr. of Manufacturing, The Harshaw Fuller & Goodwin Co.

STILLMAN, JOHN MAXSON, Stanford Univ., Cal. Professor of Chemistry.

TAKAMINE, JOKICHI, Equitable Bldg., New York, N. Y.
Consulting Chemist for Parke-Davis & Co., Detroit, Mich.

TAYLOR, DUNCAN W., 455 West 7th St., Plainfield, N. J.
Superintendent of Colgate & Co., 105 Hudson St., Jersey City, N. J.

TAYLOR, EDWARD R., Penn Yan, N. Y. Manufacturing Chemist.

TEAS, WILLIAM H., Marion, Va.
President, Marion Extract Co.

THIELE, LUDWIG A., 407 Hartman Bldg., Columbus, O.
Consulting Chemical Engineer; President, The Thiele Laboratories Co., Columbus ,O.

THOMPSON, GUSTAVE W., 129 York St., Brooklyn, N. Y.
Chief Chemist, National Lead Co.

THOMSON, HENRY N., c/o United Verde Copper Co., Clarkdale, Ariz.

THORP, FRANK H., Boston, Mass.
Asst. Prof. Industrial Chemistry, Mass. Inst. Tech.

TOCH, MAXIMILIAN, 320 Fifth Ave., New York City.
Member of firm of Toch Bros.

TUFTS, JOHN L., Winchester, Mass., P. O. Box 22. Chemical Engineer.

TYSON, GEORGE N., 2815 Gray's Ferry Rd., Philadelphia, Pa.
Supt. for the Henry Bower Chemical Manufacturing Co.

VAN HORN, WILLIAM T., 2511 Shirley Ave., Baltimore, Md.
Assistant Supt., Baltimore Plant of Mutual Chemical Co. of America.

VEILLON, A. A. L., 1800 South 2d St., St. Louis, Mo.
Vice-President and Works Manager, Monsanto Chemical Works.

VORCE, L. D., 2 Rector St., New York, N. Y.
Vice-President Tennessee Copper Co., New York, N. Y.

WAGNER, THEODORE B., 17 Battery Place, New York, N. Y.
Operating Committee, Corn Products Refining Co.

WARE, ELMER E., Ann Arbor, Mich.
Junior Professor, Chemical Engineering, University of Michigan; Consulting Chemist, Acme White Lead and Color Works, Detroit, Mich.

WESSON, DAVID, 111 South Mountain Ave., Montclair, N. J.
Manager, Tech. Dept. Southern Cotton Oil Co., 24 Broad St., New York.

WHEELER, FRANK G., 683 Harris St., Appleton, Wis.
Chemist with the Kimberly-Clark Co.

WHITAKER, M. C., Columbia Univ., New York City.
Professor of Engineering Chemistry, Columbia Univ.; Editor of Jour. of Ind. and Eng. Chemistry; Consulting Chemical Engineer.

WHITCOMB, L. R., 100 William St., New York.
Chemist and Bacteriologist in charge of Testing Lab., for Nicholas S. Hill, Jr.

WHITE, ALFRED H., 715 Church St., Ann Arbor, Mich.
Professor of Chemical Engineering, Univ. of Mich.; also Consulting Engineer.

WHITE, FRED. S., 540 1st St., Brooklyn N. Y.
Supt. Glycerine Dept., Marx & Rawolle, Brooklyn, N. Y.

WIECHMANN, FERDINAND G., 90 West St., New York City.
Consulting and Research Chemist.

WITHROW, JAS. R., Columbus, O.
Professor of Chemistry, Ohio State University. Consulting Chemist.

WOOD, F. J., 25 Clinton St., Brooklyn, N. Y.
Chief Engineer, Marx & Rawolle.

WURSTER, O. H., Morris & Co., Union Stock Yards, Chicago, Ill.

ZINSSER, FREDERICK G., Hastings-on-Hudson, N. Y.
Manufacturing Chemist under firm of Zinsser & Co.

ZITKOWSKI, HERMAN E., Rocky Ford, Colo.
Chief Chemist and Technical Adviser, American Beet Sugar Co., Denver, Colo.

ZWINGENBERGER, O. K., 1158 So. Broad St., Newark, N. J.
Patent Dept., Roessler & Hasslacher Chemical Co.

JUNIORS

ALLEN, WM. P., 768 du Pont Bldg., Wilmington, Del.
Chemist, E. I. du Pont de Nemours Powder Co.

BAUER, GEO. C., 16 West 123d St., New York, N. Y.
Supt. The Southern Cotton Oil Co., 24 Broad St., New York, N. Y.

BICKNELL, R. S., 50 E. 41st St., New York, N. Y.
Chemical Engineer, The Thermal Syndicate, Ltd., New York City, N. Y.

BOYLSTON, ARTHUR C., 3600 N. 2d St., St. Louis, Mo.
Chemist in charge of Manufacturing with the Mallinckrodt Chemical Works.

BRIERLEY, JOHN R., 432 West St., Brooklyn, N. Y.
Chemist of Edison Electric Illuminating Company of Brooklyn, N. Y., Station "Y."

CAMPBELL, CHARLES L., Wallaston, Norfolk Co., Mass.
Chemical Engineer, with E. B. Badger & Sons Co., 75 Pitts St., Boston, Mass.

CAMPBELL, WM. B., 700 University St., Montreal, Canada.
Assistant Superintendent Forest Products Laboratories, McGill University, Montreal, Quebec.

CLARK, WM. W., Heroult, Shasta Co., Cal. Noble Electric Steel Co.

FRITZ, HOWARD E., Kingsport, Tenn.
Chemical Engineer, Federal Dyestuff & Chemical Co.

GAGE, R. M., 1083 Worthington St., Springfield, Mass.
Chemical Engineer, The Fisk Rubber Co., Chicopee Falls, Mass.

GOMORY, WM. L., 72 Hinsdale Place, Newark, N. J.
Manufacturing Chemist, Universal Oil Company, New York, N. Y.

GUILLAUDEAU, ARTHUR, 4724 Winona Terrace, Cincinnati, O.
Chemist and Asst. Supt., The M. Werk Co., Murray Road, St. Bernard, O.

HAHLWEG, GEO. P., 1287 Hancock St., Brooklyn, N. Y.
Chemist with Arabol Mfg. Co., 100 William St., New York, N. Y.

HEINRICH, E. O., 3214 North 30th St., Tacoma, Wash.
Consulting and Manufacturing Chemist; Director of the Heinrich Technical Laboratories.

HELLER, HARRY, Mutual Chemical Co., Westside Ave., Jersey City, N. J.
Chemical Engineer, The Mutual Chemical Co. of America, Jersey City Plant.

HESS, J. R., 115 Broadway, New York City.
International Filtration Corporation.

HULL, FREDERICK, A., 34 Haigh Ave., Schenectady, N. Y.
Chief Chemist, Testing Laboratory, Schenectady Works, General Electric Company, Schenectady, N. Y.

JORDAN, HARRY E., 113 Monument Place, Indianapolis, Ind.
Sanitary Engineer, Indianapolis Water Co.

KLOTZ, J. R. M., 32 Liberty St., New York, N. Y.
Manager, Newport Hydro Carbon Company.

LUNN, CHARLES A., 175 Front St., New York, N. Y.
Chemical Engineer, Kinney & Lunn.

LUNT, G. P., Warrington Hall, 90 Pinehurst Ave., New York, N. Y.
Chemical Engineer, E. B. Badger & Sons Co.

MACNIDER, GEO. M., 17 Battery Place, New York, N. Y.
Chemist, Mill Starch Dept., Corn Products Refining Co., New York, N. Y.

MCAFEE, ALMER MCDUFFIE, Gulf Refining Co., Port Arthur, Tex.
Research Chemist, Gulf Refining Co.

MCINTYRE, A. G., 706–9 Traders Bank Bldg., Toronto, Can.
General Manager of Mattagami Pulp & Paper Co., Ltd., Toronto, Can.

NEWMAN, ALBERT B., Langeloth, Pa.
Chemical Engineer in charge of chemical manufacture, American Zinc & Chemical Co., Langeloth, Pa.

PEARSON, CHAS. W., 79 West 4th St., Bayonne, N. J.
Chemist, Tidewater Oil Co., Bayonne, N. J.

PETERSON, CHARLES ALBERT, Lancaster, Pa.
Chief Chemist in the Linoleum Dept. of the Armstrong Cork Co., Lancaster, Pa.

PLUMB, ROY A., 150 Farrand Ave., Highland Park, Detroit, Mich.
Manufacturing Chemists, R. A. Plumb & Co.

SCHAEFFER, JOHN A., Joplin, Mo.
Chief Chemist, Eagle Picher Lead Co., Joplin, Mo.

SEAMAN, E. H., Wantagh, L. I.
Insurance Engineer, with Underwriters at American Lloyds.

SHAFOR, RALPH W., 812 Cooper Bldg., Denver, Colo.
Chemical Engineer, The Dorr Co., Denver, Colo.

SUMMERS, FRANK P., Kingsport, Tenn.
Operating Supt., Federal Dye-Stuff and Chemical Co.

VAN DOREN, WILLARD V., 1646 Garfield Boulevard, Chicago, Ill.
Superintending Chemist of the plant of the Illinois Vinegar Mfg. Co., 48th St. & Oakley Ave., Chicago, Ill.

WOOD, BURTON G., Thompsonville, Mich.
Chemist for Desmond Charcoal & Chemical Company.

INDEX

PAGE

Alcohol ethyl, production of, from wood waste 262
Aluminum Chloride, action of, on petroleum oils and manufacture of gasolene by means of 177
Ammonia, production of, from cyanamid 267
Baruch, Edgar, resources and possibilities of chemical industry in the Southwest 1
Best, Otto, manufacture of cream tartar 91
Bleaching, notes on a new process of 219
Bleaching powder, purification of sewage by means of 156

Cements and lutes 223
Changes in the volume and specific gravity of linseed oil films on drying 251
Chemical evidence of smelter smoke injury to vegetation 25
Chemical Industry in the Southwest, resources and possibilities of 1
Coal, development in the United States of the manufacture of products derived from 209
Code of Ethics 287
Committees for 1916 291
Constitution 279
Costs as applied to professional businesses 163
Cottrell processes of electrical precipitation 35
Cream tartar, manufacture of 91
Cyanamid, production of ammonia from 267

Design and operation of ozone water purification systems 233
Development in the United States of the manufacture of products derived from coal 209
Dust-collecting system, Fleming patent 65

Electrical precipitation, Cottrell processes of 35
Electrolytic method of sewage disposal 133

Fleming patent dust-collecting system 65

Gasolene, manufacture of, by means of aluminum chloride 177
Gould, Ralph A., costs as applied to professional businesses 163

Hanna, W. C., the Fleming patent dust-collecting system 65

PAGE

Improvement of high boiling petroleum oils, and the manufacture of gasolene as a by-product therefrom, by the action of aluminum chloride..... 177
Industrial Chemistry, some American contributions to..... 199

Jordan, H. W., the development in the United States of the manufacture of products derived from coal..... 209

Landis, W. S., the production of ammonia from cyanamid..... 267
Landreth, C. P., electrolytic method of sewage disposal..... 133
Linseed oil films, changes in the volume and specific gravity of, on drying.. 251
Little, Arthur D., the utilization of wood waste..... 257
Lutes and cements..... 223

Manufacture of cream tartar..... 91
McAfee, A. M., the improvement of high boiling petroleum oils, and the manufacture of gasolene as a by-product therefrom, by the action of aluminum chloride..... 177
Members, list of..... 294
Mitchell, J. P., chemical evidence of smelter smoke injury to vegetation... 25

New electrolytic method of sewage disposal..... 133
Notes on a new process of bleaching..... 219

Officers for 1916..... 291
Olsen, J. C., a new electrolytic method of sewage disposal..... 133
Ozone water-purification systems, design and operation of..... 233

Peckham, S. F., notes on a new process of bleaching..... 219
Petroleum oils, improvement of, and manufacture of gasolene therefrom, by the action of aluminum chloride..... 177
Powell, Sheppard, T., design and operation of water-purification systems... 233
Production of ammonia from cyanamid..... 267
Professional businesses, costs as applied to..... 163

Resources and Possibilities of chemical industry in the Southwest..... 1

Sadtler, S.S., lutes and cements..... 223
Sadtler, Samuel P., some American contributions to industrial chemistry... 199
Schmidt, Walter A., Cottrell processes of electrical precipitation..... 35
Sewage disposal, a new electrolytic method of..... 133
Sewage, purification of, by means of bleaching powder..... 156
Sieman-De Frise, ozone water-purification system..... 234
Smelter smoke injury to vegetation, Chemical evidence of..... 25
Some American contributions to industrial chemistry..... 199
Sulphur content of vegetation..... 30
Sulphur dioxide, effect of, on vegetation..... 26
Sulphur fumes, the thiogen process for removing..... 81

PAGE

Tartaric acid, manufacture of..... 100
The utilization of wood waste..... 257
Thiogen process for removing sulphur fumes..... 81
Thompson, G. W., changes in the volume and specific gravity of linseed oil films on drying..... 251

Water-purification systems, design and operation of, by means of ozone.... 233
Wood waste, the utilization of..... 257

Young, S. W., the thiogen process for removing sulphur fumes..... 81

PERIODICAL